CHAPTER 11

DESIGN AND LAYOUT

Section I. PATTERN MAKING

11-1. Introduction

The shapes into which flat metal sheets must be cut so that they can be made up into the desired article are known as patterns. Patterns are drawn or developed from dimensioned sketches of the objects to be made. They may be drawn on paper or on the metal sheet itself. When an object is to be duplicated many times, a pattern may be cut of sheet metal and traced over and over again.

11-2. Sketches

The first step in the development of a pattern is usually a three-dimensional sketch of the item to be made showing all necessary dimensions. Sketching is a skill that can be acquired by anyone who is able to write. Sketches of the most complicated objects are developed by simple step-by-step procedures. These procedures can be learned from practice with simpler objects. A sketch of the tool box shown in figure 11-1 can be developed as shown in figure 11-2. First, draw the front; second, add a foreshortened view of one side; third, draw in what can be seen of the back and the other side, taking care to see that the edges shown are parallel with the front and side previously drawn; fourth, add the hinged top; and fifth, show all necessary dimensions.

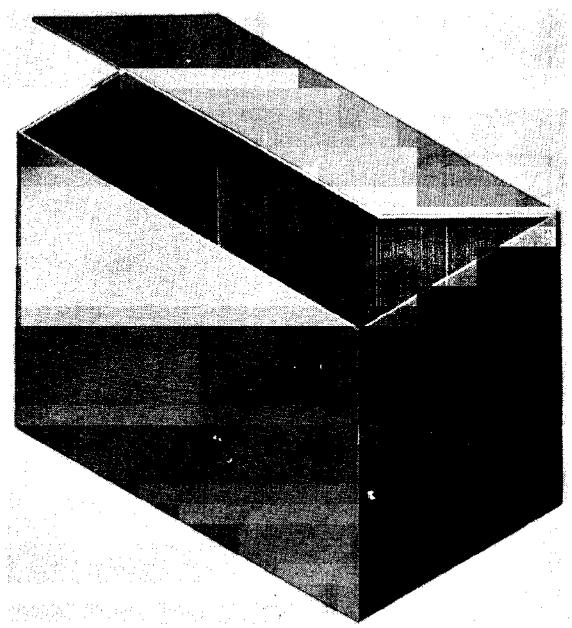


Figure 11-1. Tool box.

11-3. Three-View Drawing

After a three-dimensional sketch has been made, the next step in the development of a pattern is usually the preparation of a three-view drawing which shows how the object appears when viewed directly from the front, side, and top. These drawings are made to scale and should include all necessary dimensions. A three-view drawing of the tool box is shown in figure 11-3.

11-4. Patterns

a. Definition. A pattern is a full-view drawing of an object with all the surfaces of the object shown in one plane. If the object is assembled from several pieces, there will be a separate pattern for each piece.

b. Methods of Development. Patterns may be laid out by one of three methods; parallel lines, radial lines, or triangulation. They may also be developed by the rollout method. Each method is particularly useful in a certain type of work.

c. Flaps. Where two sheet metal edges are to

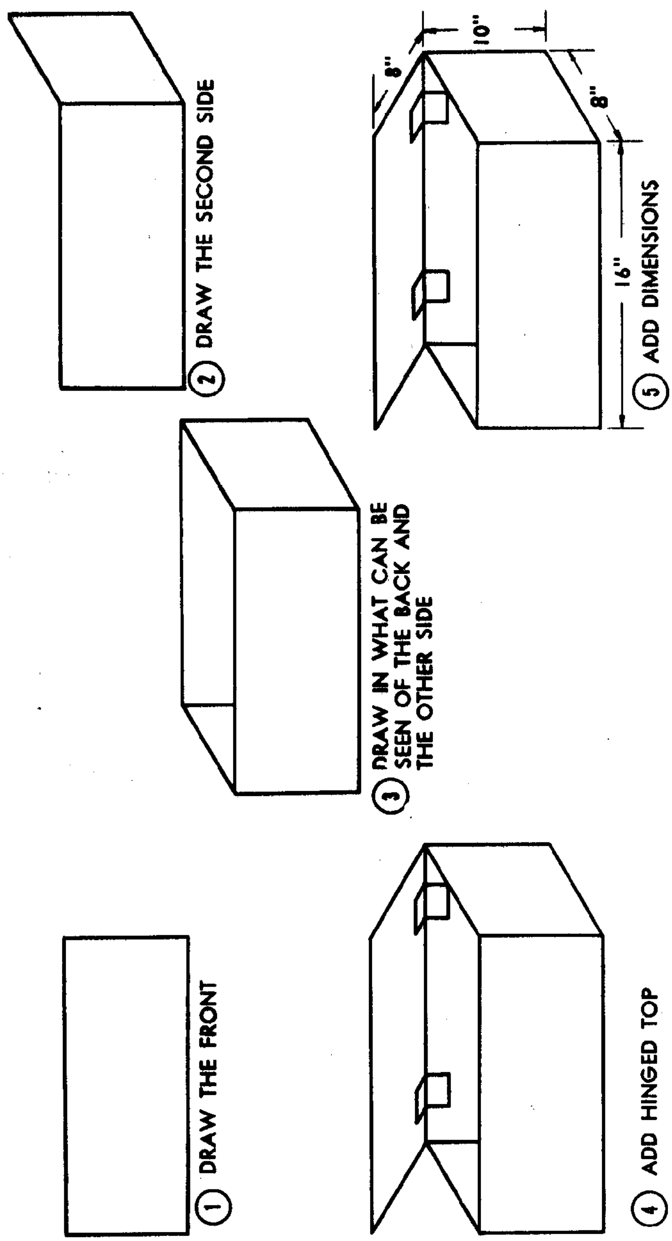


Figure 11-2. Step-by-step method of drawing tool box.

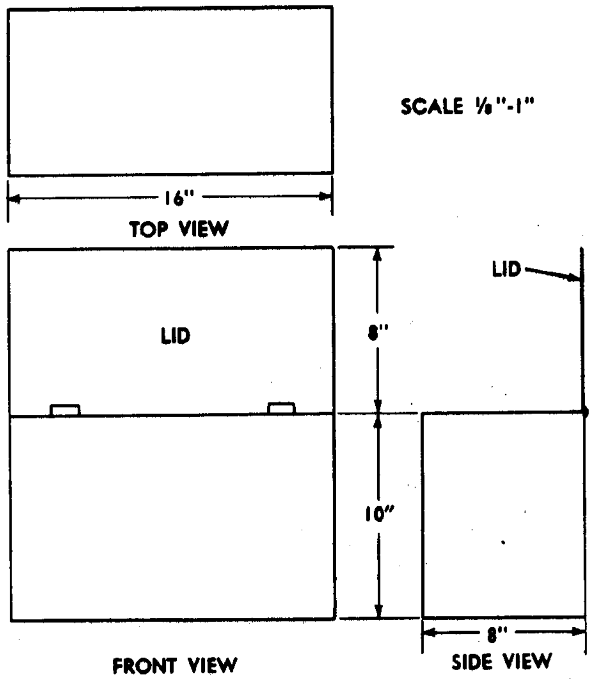


Figure 11-3. Three-view drawing of tool box.

be joined together, the pattern should include flaps on one or both of the edges for use in making the joint. These flaps will vary from ¼ to ¾ inches in width, depending on the type of joint used.

11-5. Development by Parallel Line

Development by parallel lines can be used whenever the three-view drawing shows the true lengths of all lines needed to develop the pattern.

a. Rectangular Figure. To develop a pattern for the tool box ((1), (2), fig. 11-4), first draw a full scale plan view of the bottom ((3), fig. 11-4), making sure that all corners are square and that the length of the front and sides is as shown in the three-view drawing. Next, the sides are added to the bottom by extending lines 1-2 and 3-4 a distance of 6 inches in each direction and marking points 5, 6, 9, 10. Then draw lines 5-6 and 9-10 ((4), fig. 11-4). Next, draw the ends of the box by extending lines 1-4 and 2-3 6 inches in each direction and locating points 7, 8, 11, and 12 ((5), fig. 11-4). Draw lines 7-8 and 11-12. The height of the sides may also be drawn, or checked by the use of a compass, as shown by the arc 9-11, which is drawn by a compass centered on point 2. A pattern of the box, less top, is completed by adding flaps at the fold lines as shown in figure 11-5.

b. Cylindrical Figure. The parallel line method may also be used to lay out patterns

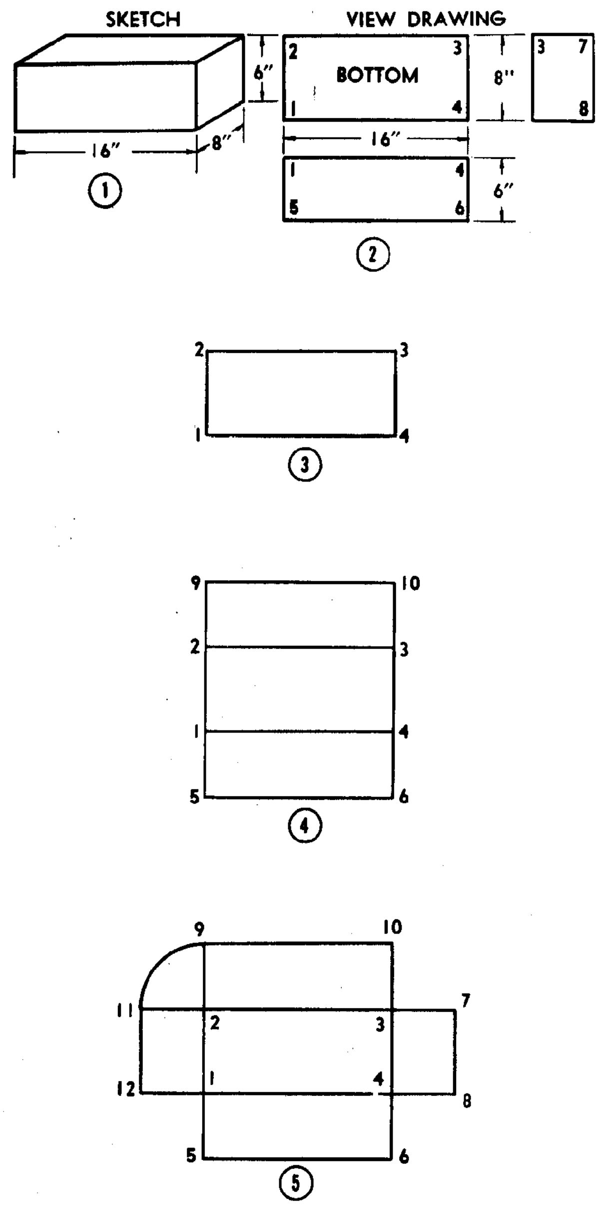


Figure 11-4. Development of pattern for tool box.

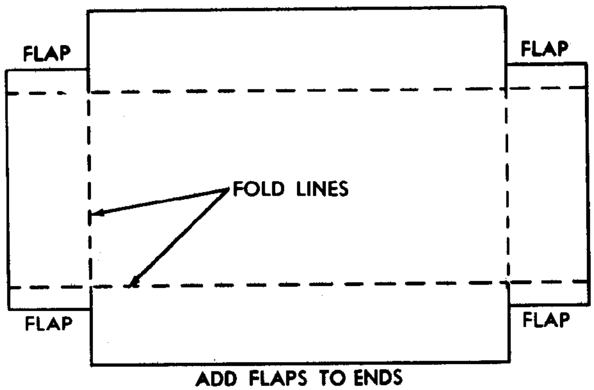


Figure 11-5. Finishing pattern with flaps and fold lines.

for round pipe. Patterns for fittings made up of round pipe intersecting at an angle, such as that shown in (1), figure 11-6 may be developed by the following method:

(1) Prepare a three-view drawing with dimensions, as shown in (2), figure 11-6.

(2) Redraw the top and front view to full scale as shown in figure 11-7.

(3) At any convenient distance from the top view draw the construction circle for pipe *A*. All construction lines are shown dotted in figure 11-7. The center of this circle is on the axis of pipe *A*. Divide this circle into 12 equal parts and number them as shown.

(4) On the front view, draw the construction semicircle for pipe *A*. The center of the semicircle is on the axis of pipe *A*. Divide the semicircle into six equal parts and number them as shown.

(5) On the top view, draw lines from point 0 through 6 parallel to the axis of pipe *A* and intersecting pipe *B* at points 0′ through 6′.

(6) On the front view, draw lines from point 0 through 6 of the construction semicircle for pipe *A* parallel to the axis of pipe *A*. Extend these lines until they intersect the lines parallel to the axis of pipe *B* and drawn from corresponding numbered points 0′ through 6′ of the top view. Label these points of intersection 0″ through 6″.

(7) To lay out the pattern for pipe *A*, draw a base line *MN* perpendicular to the axis of pipe *A* on a front view. The length of *MN* equals the circumference of pipe *A*, which is 3.1416 times the diameter of pipe *A*. Divide the base line *MN* into 12 equal parts and number them as shown.

(8) On the pattern for pipe *A* draw lines perpendicular to base line *MN* at points *0* through 6.

(9) On the front view, draw lines from point 0″ through 6″ perpendicular to the axis of pipe *A*. Extend these lines until they intersect corresponding numbered lines drawn in step 7 above.

(10) Connect these points of intersection with a smooth curve, completing the pattern for pipe *A*.

(11) To lay out the pattern for pipe *B*, extend lines *DE* and *FG* and lay off base line *PQ*. The length of *PQ* equals the circumference of pipe *B*. Draw line *PR* and *QS* perpendicular to *PQ*.

(12) Locate point *0* on the base line midway between *P* and *Q*.

(13) From point *0* locate point 1 at a distance equal to the distance from 0′ to 1′ measured along the curve in the top view of pipe *B*. The curved distance can be measured by using the edge of a sheet of paper or by stepping off small divisions with dividers. Similarly locate points 2 and 3 on the pattern for pipe *B*, using corresponding distances measured along the curve in the top view of pipe *B*.

(14) On the pattern for pipe *B* draw a line perpendicular to *PQ* from the point *0* through 3 and add numbers 4, 5, and 6 as shown.

(15) Draw a line parallel to *PQ* from point 0″ through 6″ on the front view intersecting the correspondingly numbered vertical lines drawn in step 14 above.

(16) Connect these points of intersection in a smooth curve. This curve marks the opening in pipe *B*, completing the pattern.

(17) Add flaps where required.

11-6. Development by Radial Line

The radial line method is used to make pat-

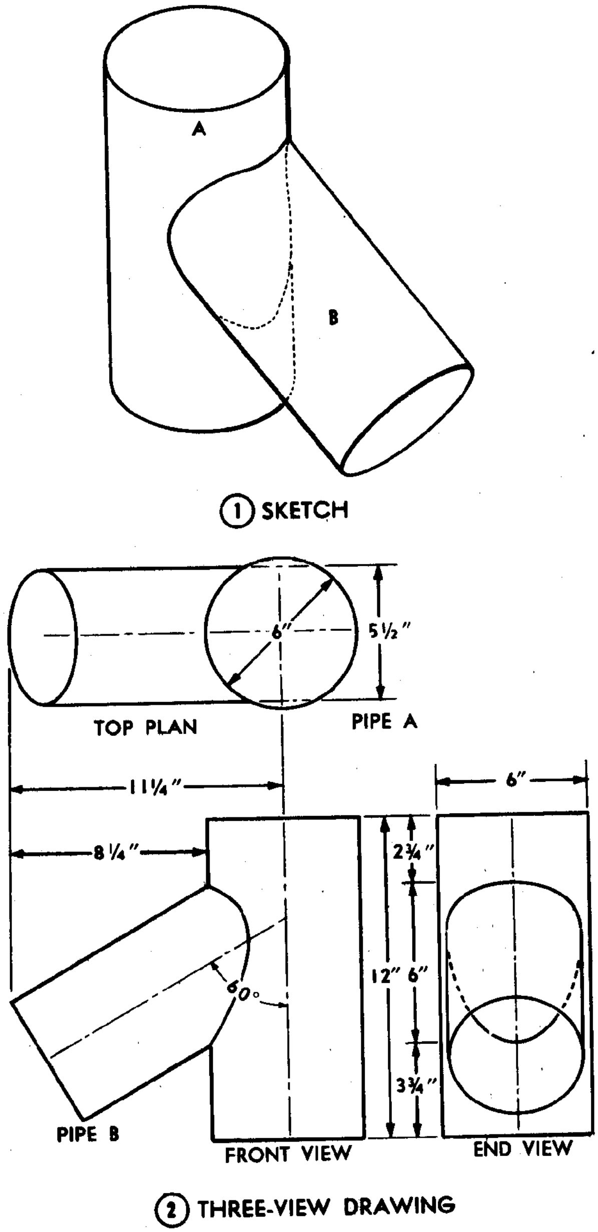


Figure 11-6. Sketch and three-view drawing of intersecting round pipes.

terns for pyramids and cones. A compass or dividers will be required.

a. Pyramid. A pattern for the square base pyramid shown in (1), figure 11-8 can be developed as follows:

(1) Prepare a three-view drawing with dimensions, positioned so that one vertical edge of the pyramid is parallel to the plane of the elevation drawing and shows in its true length ((2), fig. 11-8).

(2) To begin the pattern, lay off line 1-2 equal in length to one vertical edge of the pyramid ((1), fig. 11-9).

(3) Scribe an arc the length of one side of the base, using point 1 as the center.

(4) Scribe an arc the length of one vertical edge, using point 2 as the center, and locate point 3 at the intersection of the two arcs.

(5) Draw lines 2-3 and 1-3 to make one face of the pyramid ((2), fig. 11-9).

(6) Locate points 4, 5, and 6 in the same manner and draw lines 3-4, 2-4, 4-5, 2-5, 5-6, and 2-6 to complete the faces of the pyramid.

(7) Add a flap and draw in the fold line ((3), fig. 11-9).

b. Cones. The pattern for a truncated cone such as that making the upper portion of the funnel shown in (1), figure 11-10 can be developed as follows:

(1) Prepare a three-view drawing with dimensions as shown in (2), figure 11-10.

(2) Divide the top circumference view into 32 or more equal parts.

(3) Draw the side view of the funnel top *ABCD* and extend the sides until they intersect at point *E* (fig. 11-11).

(4) Select a point *P* on the extension of the centerline of the funnel and draw line *00-P* parallel to and the same length as *ADE*.

(5) Using *P* as a center and *OP* as a radius, swing arc *Ob*. Using *OP* as a radius swing arc *Oa*.

(6) With dividers mark off 32 equal divisions of arc *Ob*, each division equil in length to one of the 32 divisions marked off in (2), figure 11-10.

(7) Draw line *P*-32 and add a flap. The pattern for the funnel spout can be developed by the same method.

11-7. Development by Triangulation

The method of triangulation is used to lay out

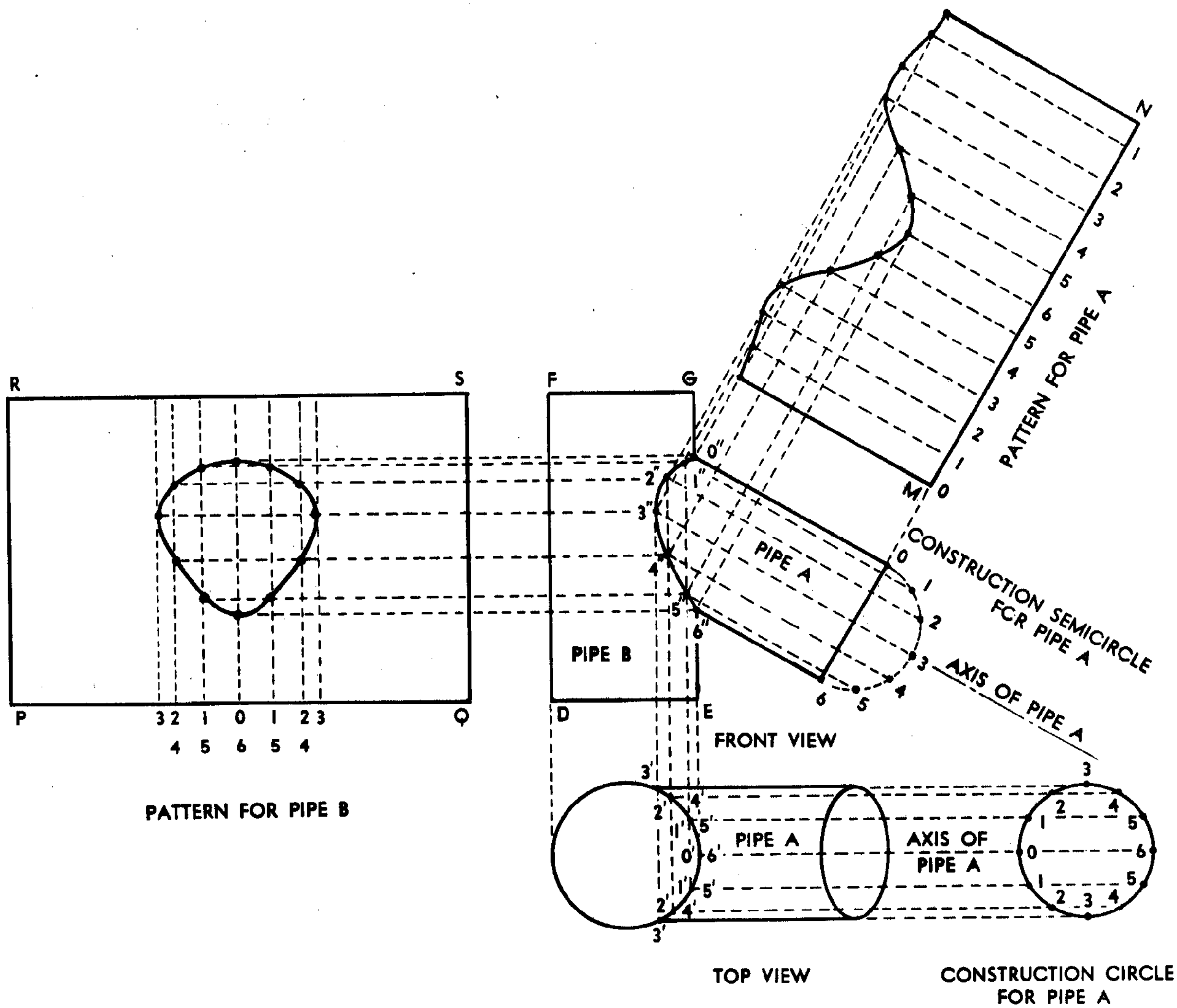


Figure 11–7. Development of pattern for intersecting round pipes.

patterns for irregularly shaped objects. The surface of the object is assumed to be made up of thin triangular elements. In developing the pattern it is necessary to first find the "true lengths" of the elements, and then lay them on the pattern. A pattern for the off-centered truncated cone sketched in (1), figure 11–12 and shown in a two-view drawing in (2), figure 11–12 can be developed as follows:

a. Draw and dimension a full size elevation and half plan as shown in (1), figure 11–13.

b. Divide the circles on the half plan into six or more equal parts and number the divisions.

c. Connect each of these divisions with straight lines. The lines are alternately solid and dotted to make construction of "true lengths" less confusing.

d. Draw lines *AB* and *CD* perpendicular to a baseline and equal in length to the height of the truncated cone ((2), fig. 11–13).

e. From the half plan, lay off lengths 1–2, 3–4, 5–6, and so forth on the base line, measuring each distance from *A*. Draw lines connecting these points with *B*. From the half plan lay off lengths 2–3, 4–5, 6–7, and so forth on the baseline, measuring each distance from *C*.

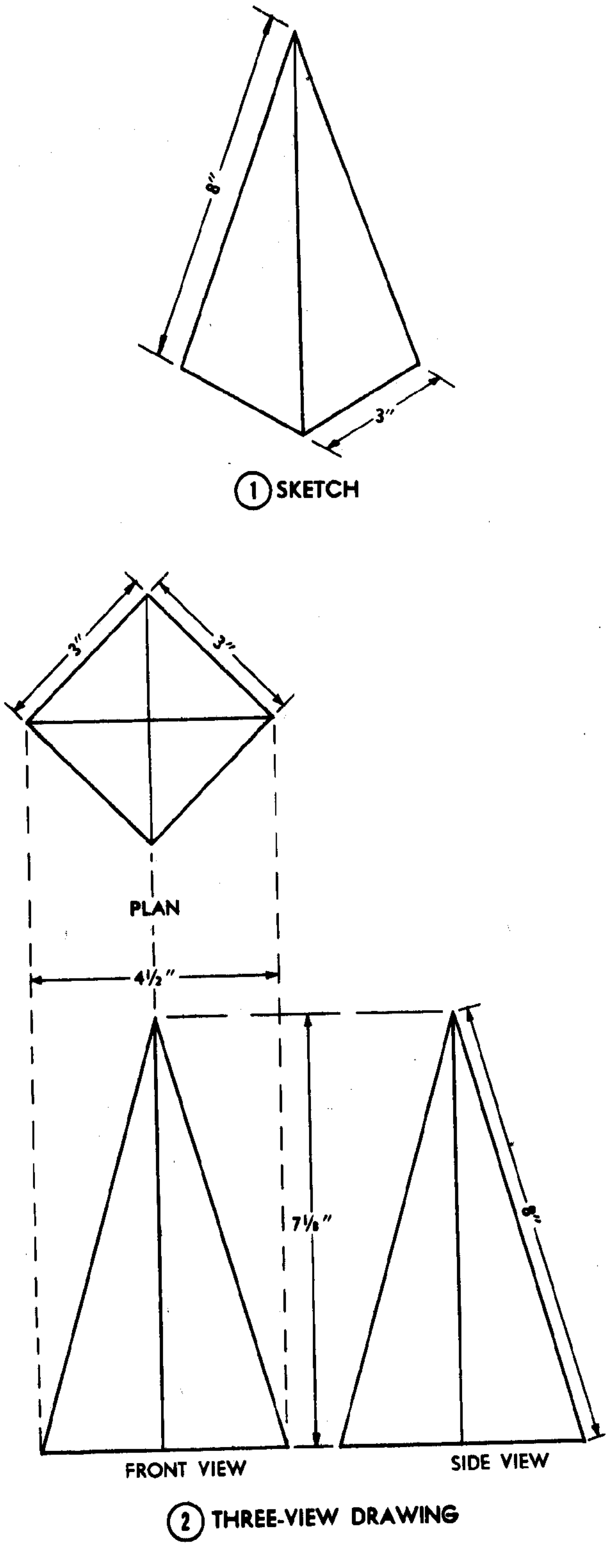


Figure 11-8. Sketch and three-view drawing of square base pyramid.

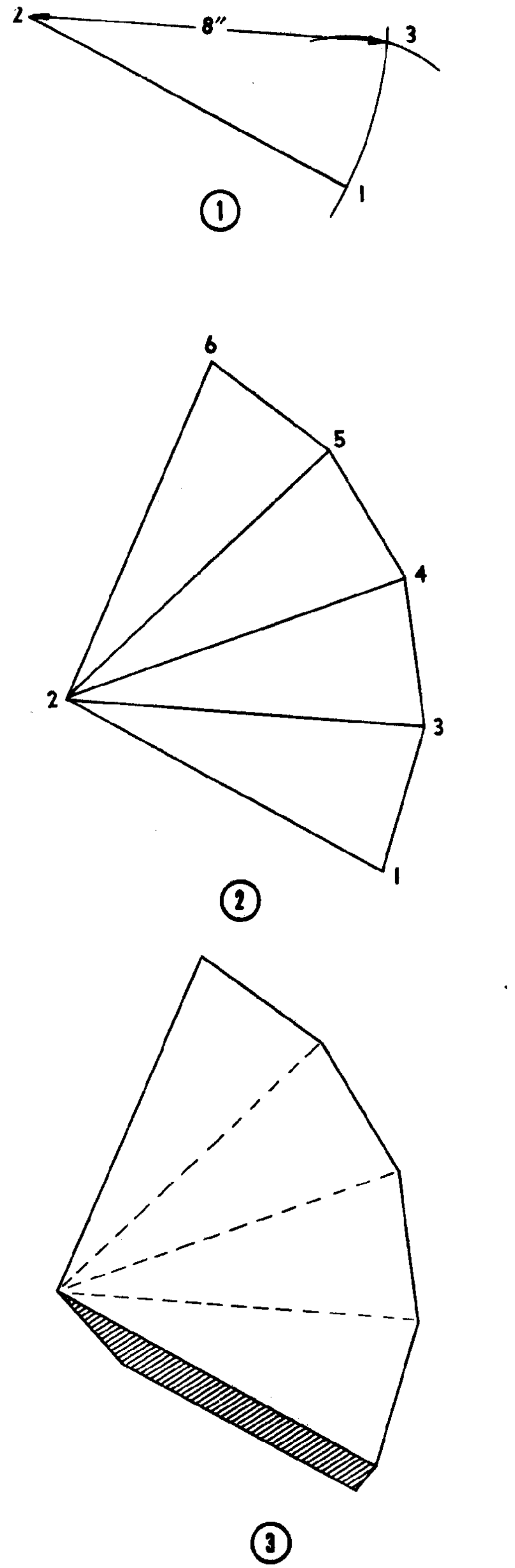


Figure 11-9. Development of pattern for square base pyramid.

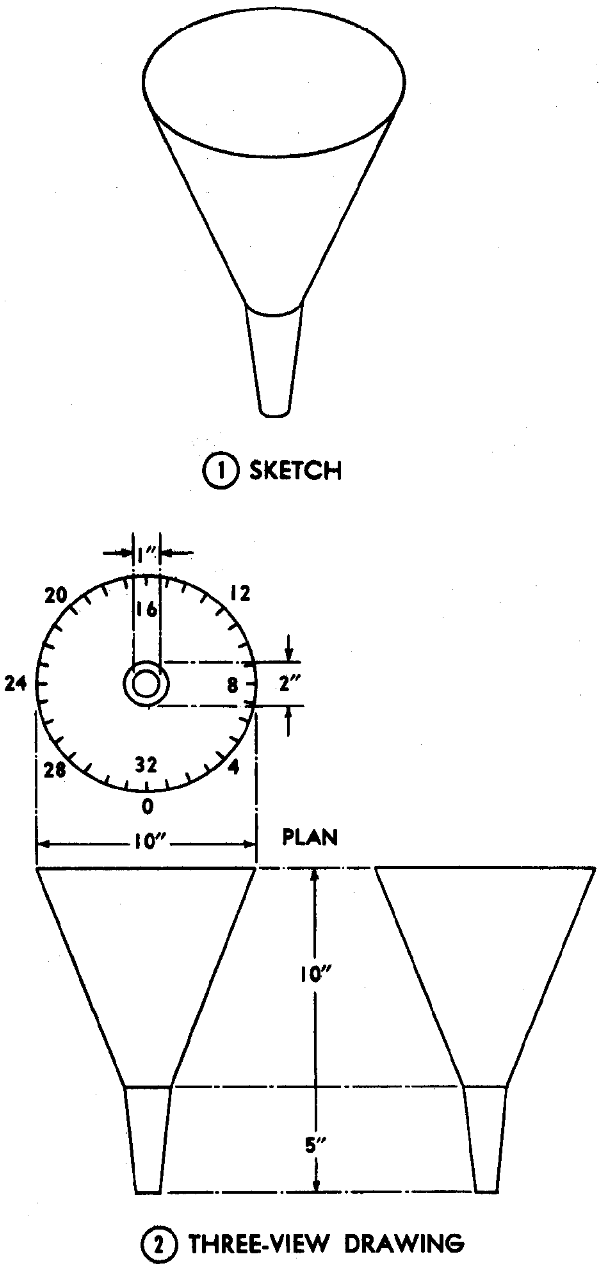


Figure 11–10. Sketch and three-view drawing of funnel.

Connect each of the parts with *D*. These lines are the "true lengths" of the surface elements.

f. To lay out the pattern, draw line 1–2 ((3), fig. 11–13). Its length is taken from line *B* 1–2 shown in the element development. With a compass, swing an arc using 1 as a center and length 1–3 from the half plan as a radius.

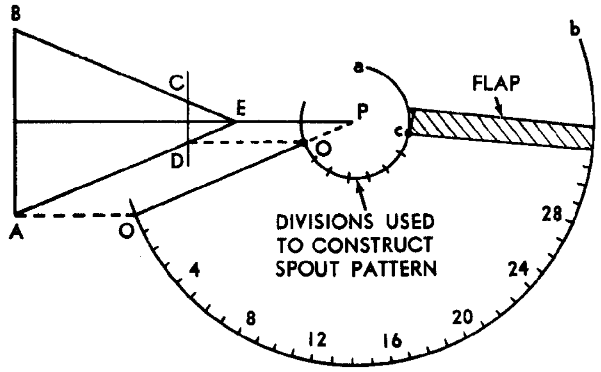


Figure 11–11. Development of pattern for funnel using the radial line method.

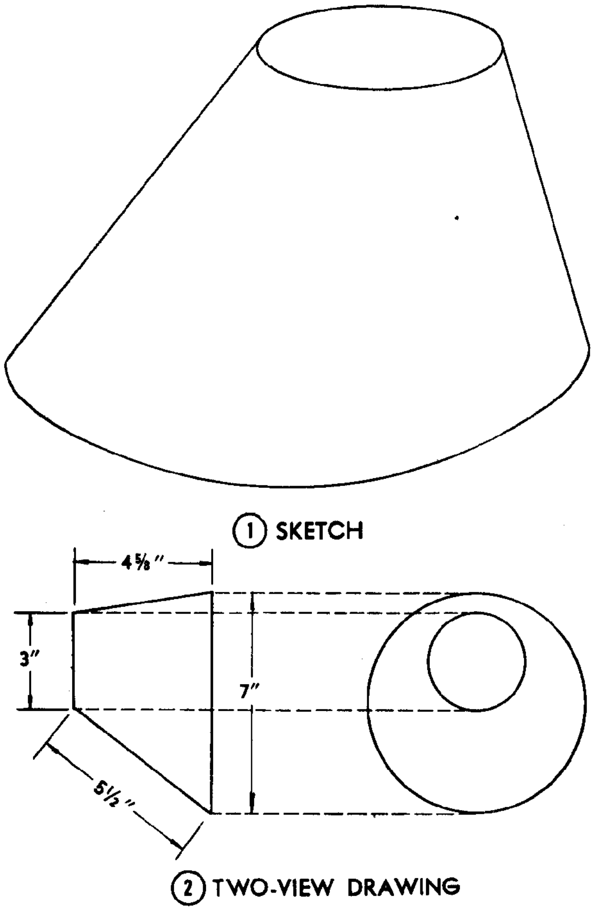


Figure 11–12. Sketch and two-view drawing of off-centered truncated cone.

Using 2 as a center and *D* 2–3 as a radius, swing another arc to intersect the first. This locates point 3.

g. In a similar manner, locate points 4 to 14. Connect the odd points 1, 3, 5, 7, 9, 11, and 13 with a smooth curve; and 13 and 14 with a straight line.

h. This completes a half pattern. The other half of the pattern can be made by completing another set of elements starting at 1–2 and proceeding to the right in the same order. Add a flap to one end of the pattern to provide for a joint.

11–8. Rollout Patterns

The rollout method of pattern layout can be used for objects with flat or simply curved sides which are symmetrical about one center plane. The following examples will give an

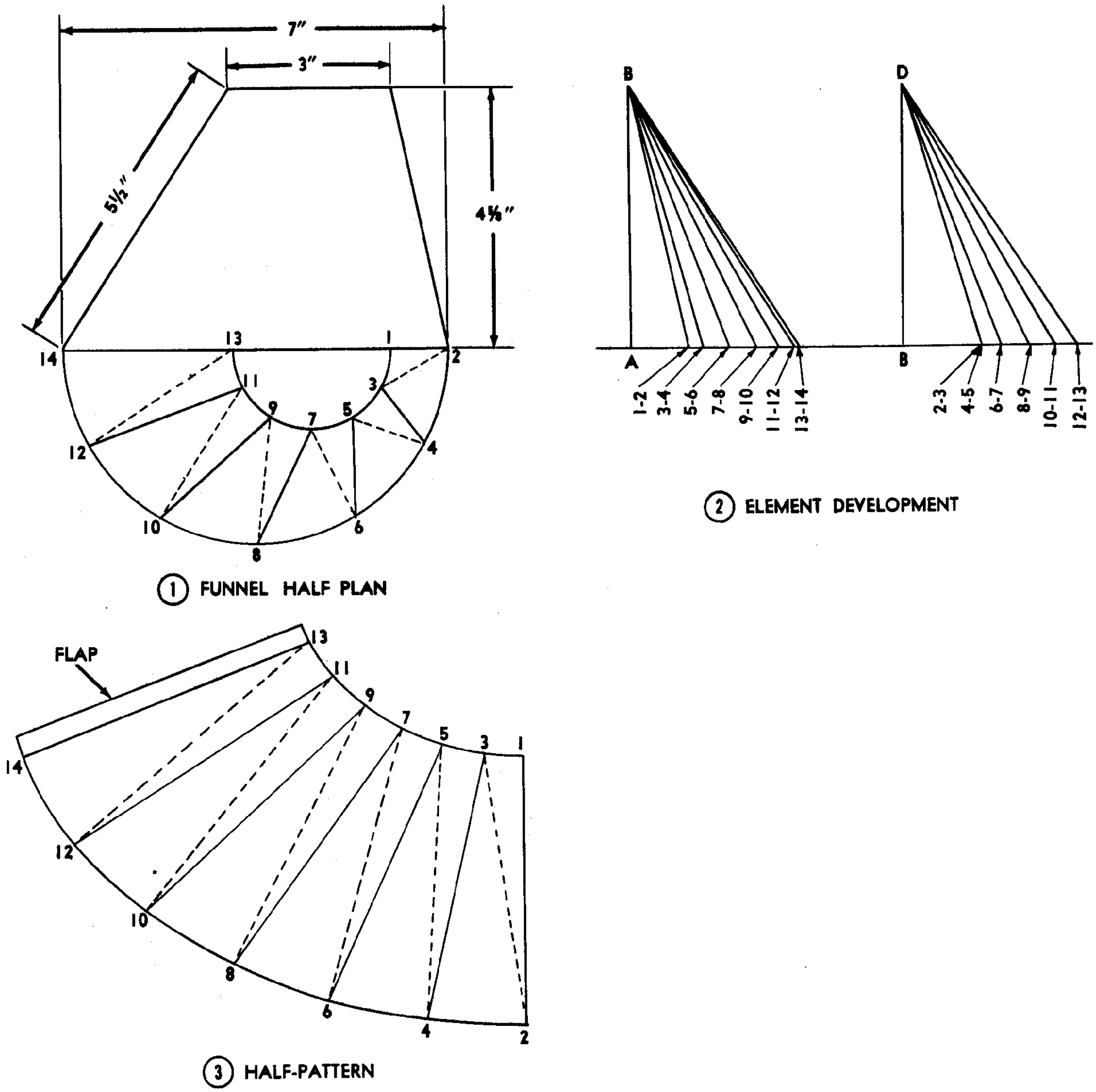


Figure 11–13. Development of pattern for off-centered truncated cone.

idea of their range of use. These patterns are made of sheet metal and are principally used for objects that are to be duplicated several times.

a. Funnel Top. The pattern for the top of the funnel sketched in figure (1), 11-10 and shown in a two-view drawing in figure 11-14 can be developed as follows:

(1) Mark the side elevation and centerline of the funnel on a piece scrap metal with a scratch awl and straightedge ((1), fig. 11-15).

(2) Lay out half plan of the top and bottom views of the funnel on the fold line.

(3) Cut the pattern along the outline and fold the half plans upward at right angles to the sheet along the fold lines ((2), fig 11-15).

(4) Put ink on the outer edges of the pattern (3), fig. 11-15).

(5) Roll the pattern on paper as shown in (4), figure 11-15 to trace a half pattern outline.

(6) To make a whole pattern from a half pattern, fold the paper along either end of the

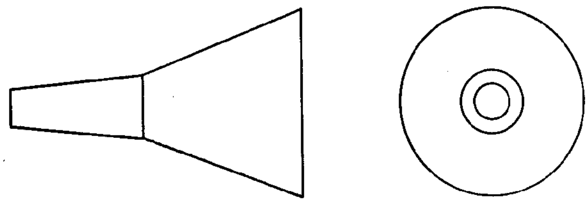


Figure 11-14. Two-view drawing of funnel.

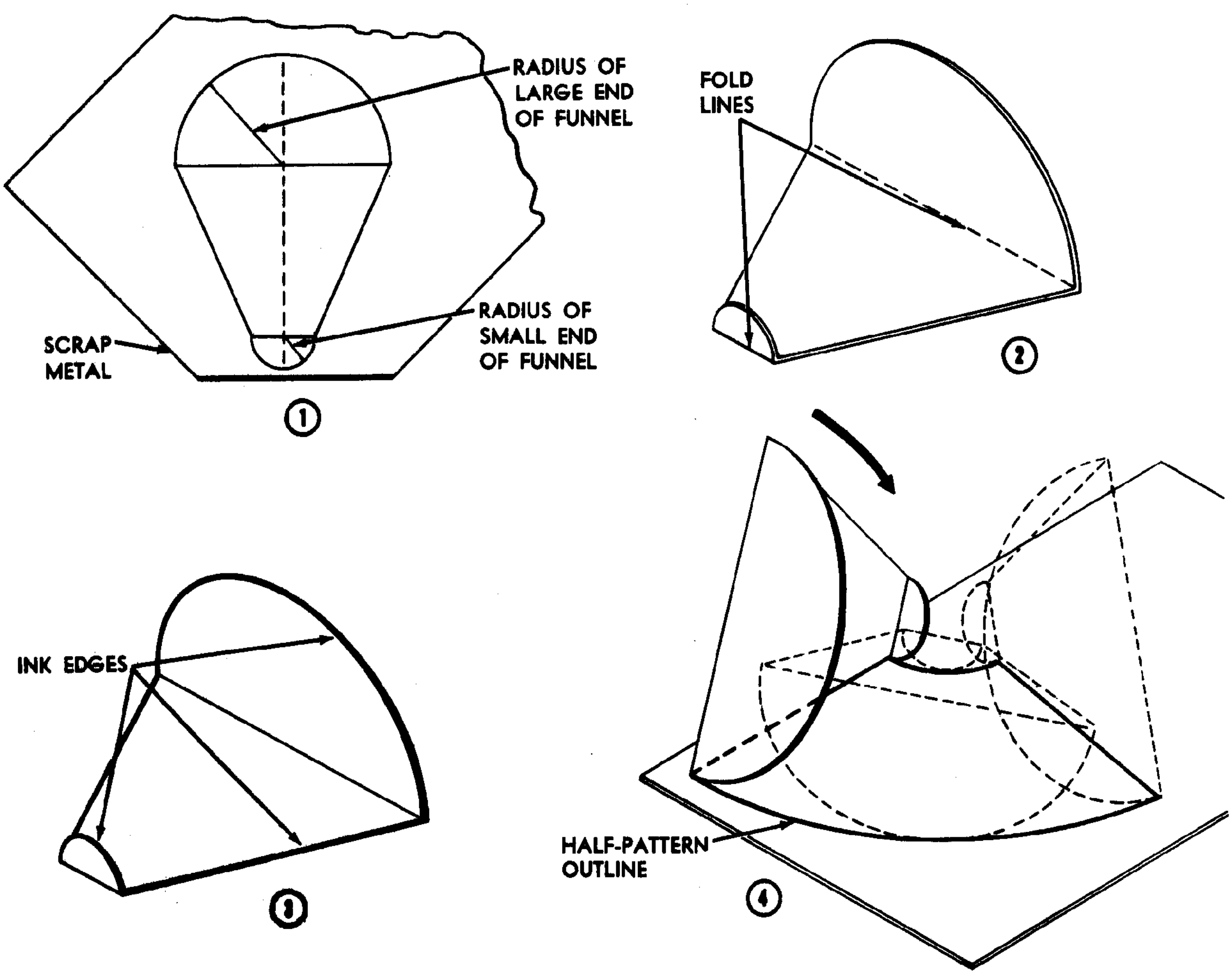


Figure 11-15. Development of pattern for funnel using the roll-out method.

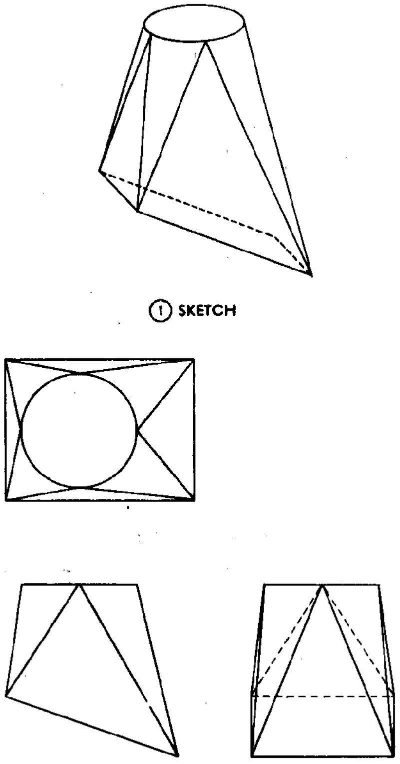


Figure 11-16. Sketch and three-view drawing of hood portion of chimney jack.

pattern and cut along the curved line. Leave enough paper at one end to form a flap.

b. Chimney Jack. In a similar manner, a rollout pattern for the hood portion of a chimney jack, shown in figure 11-16 can be prepared as shown in figure 11-17.

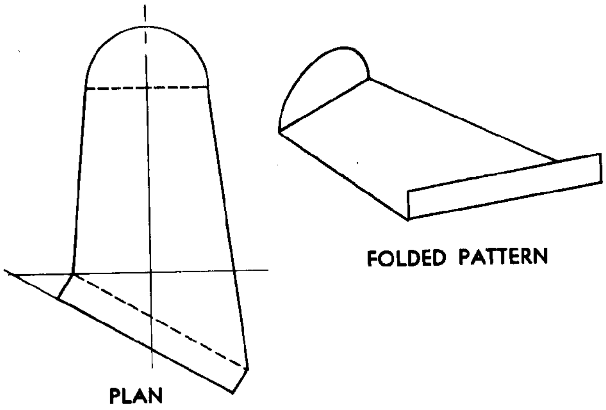


Figure 11-17. Development of pattern for hood portion of chimney jack.

Section II. AIR DUCTS

11-9. Elements of Design

Pressure losses in duct systems result from friction of the air along the inner surfaces of the duct and from dynamic losses resulting from sudden changes in direction of air flow or sudden enlargement or reduction in duct size. Good air duct design therefore requires that:

a. Inner duct surfaces and joints be as smooth as practicable. Sheet metal is an excellent material for this purpose, being superior to materials such as wood or masonry.

b. Sharp elbows and bends are avoided. Splitters and turning vanes can be used to reduce turbulence and pressure losses in elbows.

c. Diverging transition fittings are made as long as practicable. Round ducts or rectangular ducts which are as near square in cross section as possible will offer the least surface area for resistance to air flow.

11-10. Elbows

a. Characteristics. Tests of pressure losses in elbows of various types have shown that:

(1) The pressure loss decreases as the radius of the elbow increases, and a centerline radius of $1\frac{1}{2}$ times the width of the elbow in the plane of the turn is considered good design.

(2) The pressure loss in flat elbows is greater than that in elbows of ducts of equal size in which the turn is made in the plane of the narrow dimension. Air packs up and creates turbulence along the outer edge of a wide turn.

(3) The resistance of wide elbows or of elbows made with little or no inner radius can be greatly reduced by the use of turning vanes which in effect convert a large elbow into a number of smaller ones.

b. Typical Fittings.

(1) A round throat elbow of good design

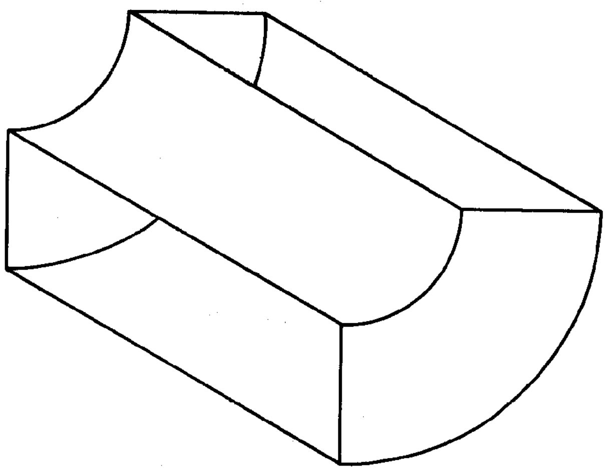


Figure 11-18. Round throat elbow.

is shown in figure 11-18 and a pattern for this elbow is developed in figure 11-19.

(2) A square throat elbow to which turning vanes have been added is shown in figure 11-20 and a corresponding pattern is developed in figure 11-21.

(3) A register box or stack head, which is really a special type of elbow, is shown in figure 11-22 and the pattern is given in figure 11-23. This fitting is used to terminate a vertical riser stack and provide the means for attaching a register or grille.

11-11. Transition Fittings

a. Description. Transition fittings are used to change the dimension of a duct with or with-

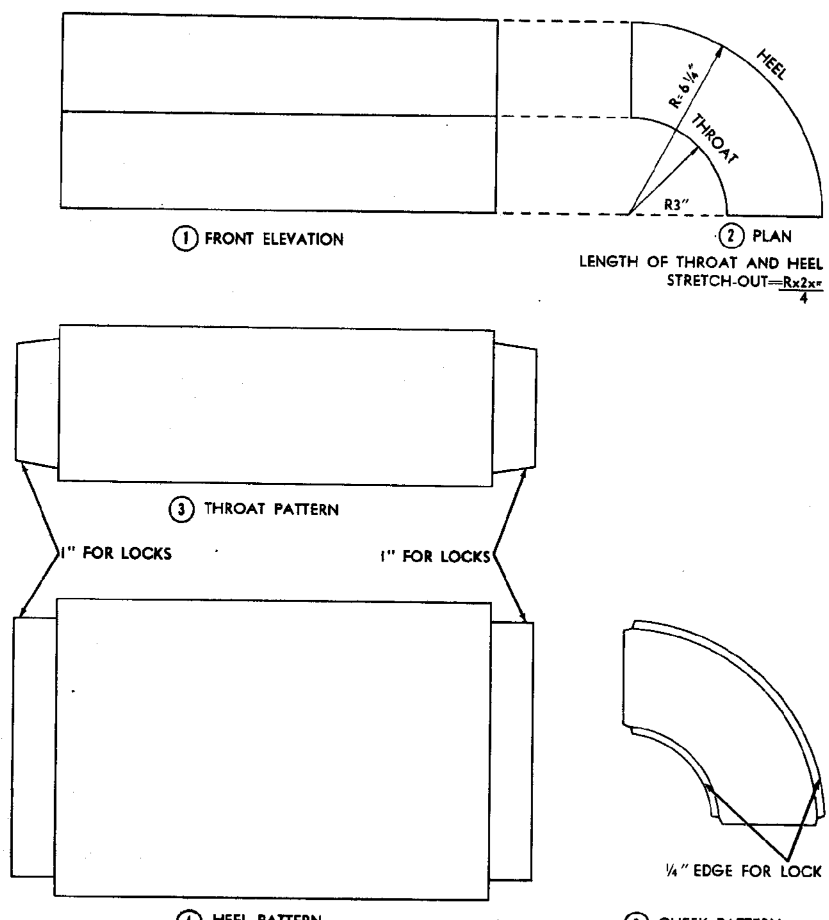


Figure 11-19. Pattern for round throat elbow.

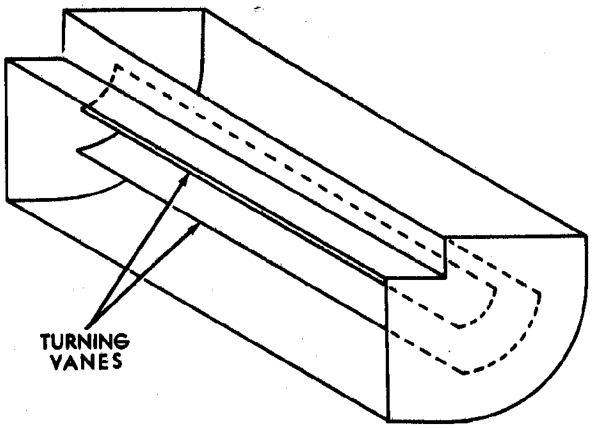


Figure 11-20. Square throat elbow with turning vanes.

out changing its total cross-sectional area. They are made as long as practicable and contain smooth curves where necessary in order to reduce turbulence and friction losses.

b. Typical Fittings.

(1) A straight transition fitting is shown in figure 11-24 and its pattern is shown in figure 11-25.

(2) A transition may also be combined with an elbow as shown in figure 11-26 with a corresponding pattern in figure 11-27.

(3) Fittings used to change the line in which a duct is running to a new position parallel to the original line are known as jumps

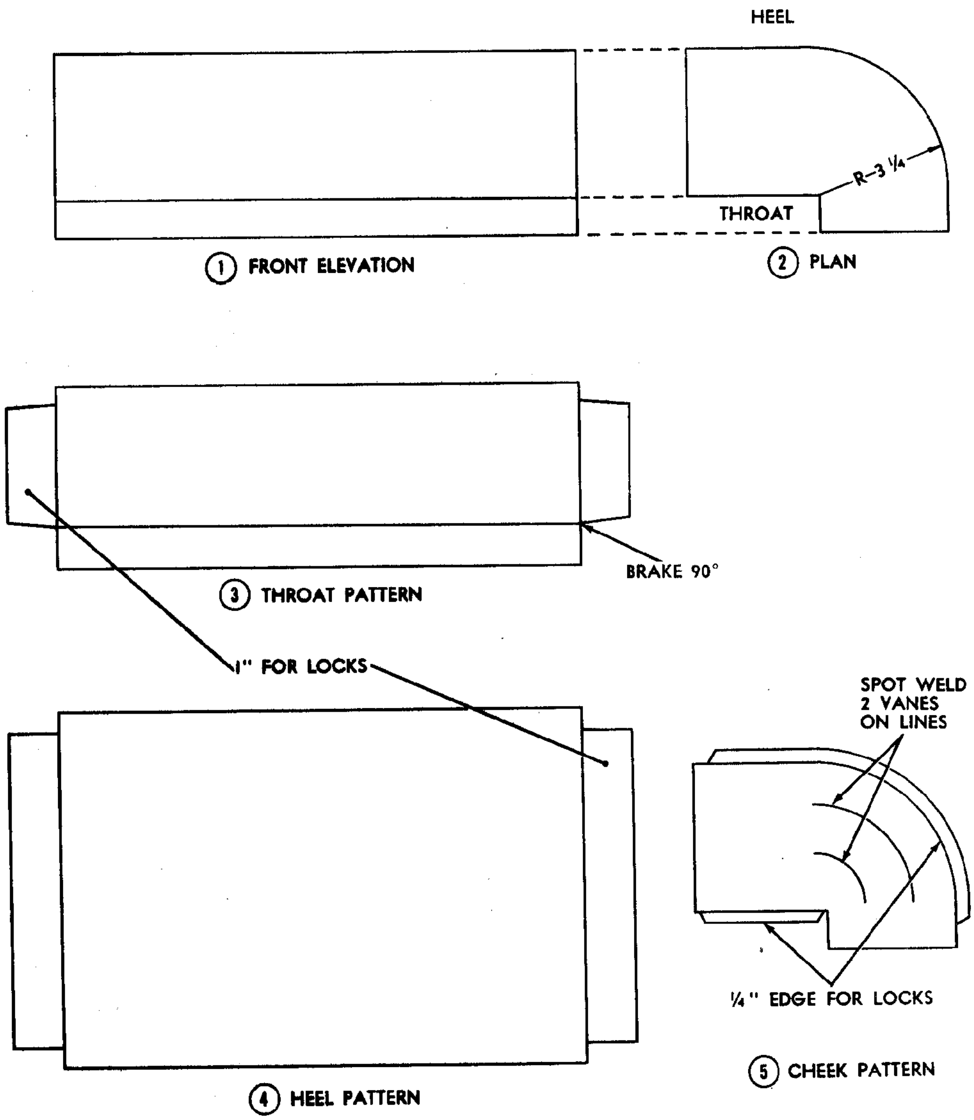


Figure 11-21. Pattern for square throat elbow with turning vanes.

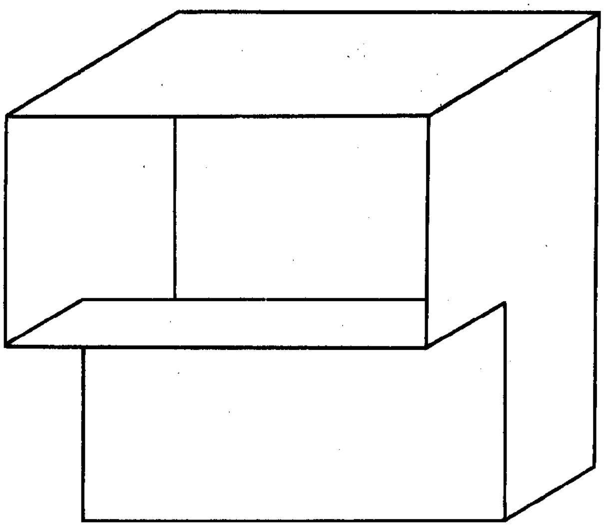


Figure 11–22. Register box.

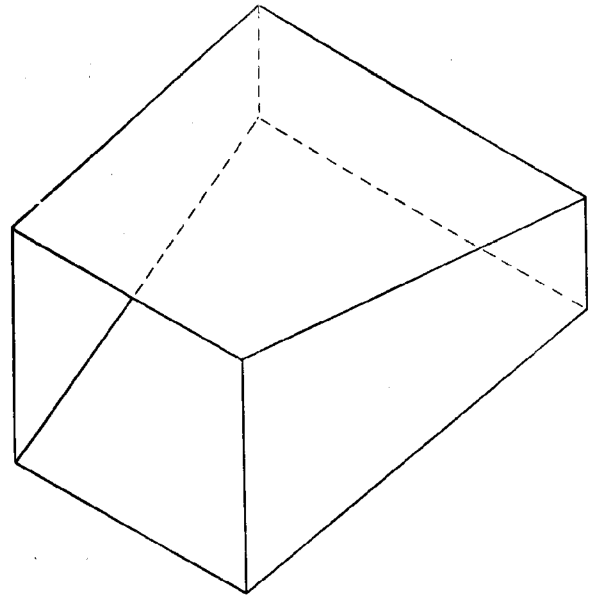


Figure 11–24. Straight transition.

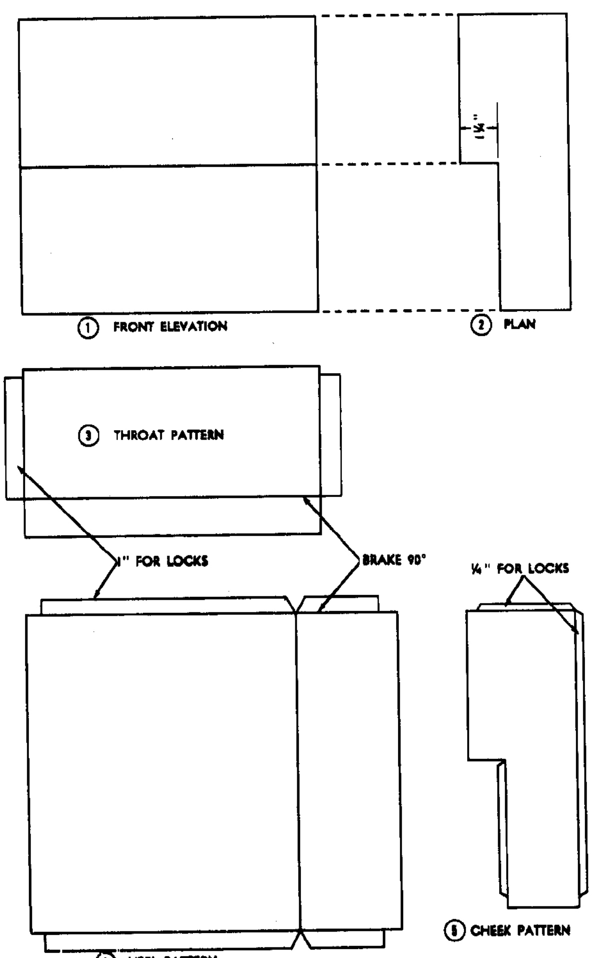


Figure 11–23. Pattern for register box.

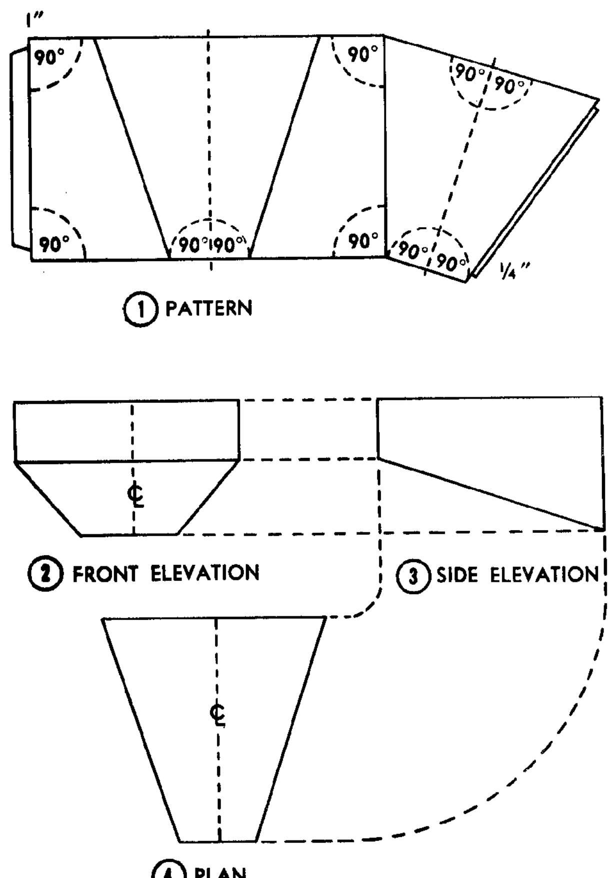


Figure 11–25. Pattern for straight transition.

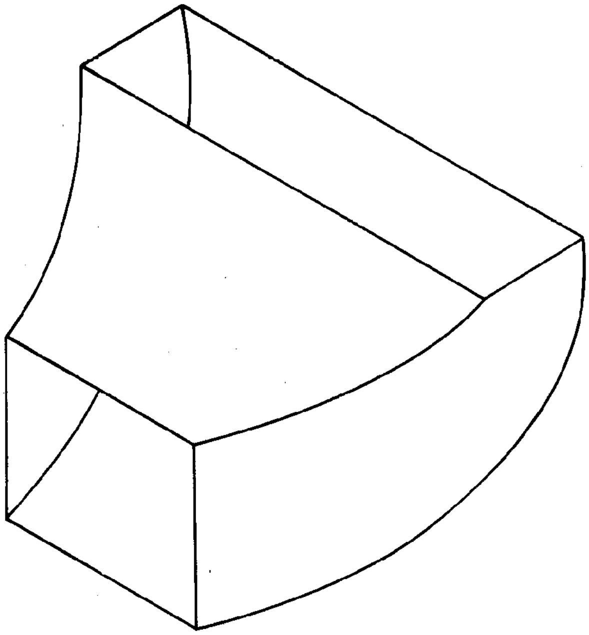


Figure 11-26. Transition elbow.

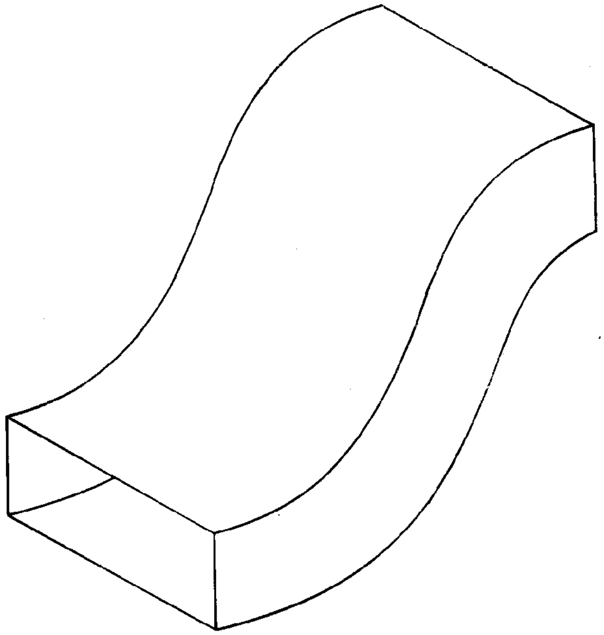


Figure 11-28. Jump fitting.

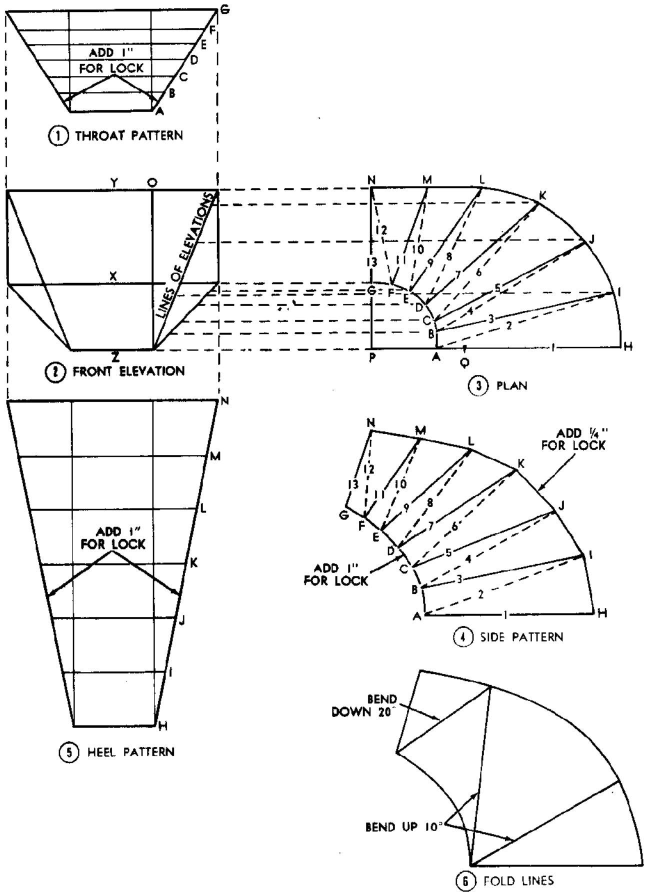


Figure 11-27. Pattern for transition elbow.

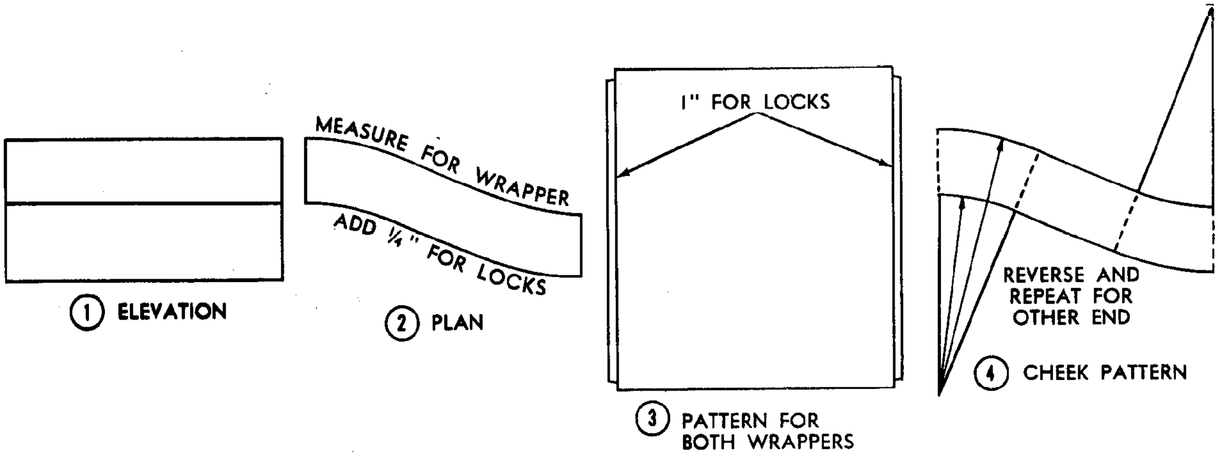


Figure 11-29. Pattern for jump fitting.

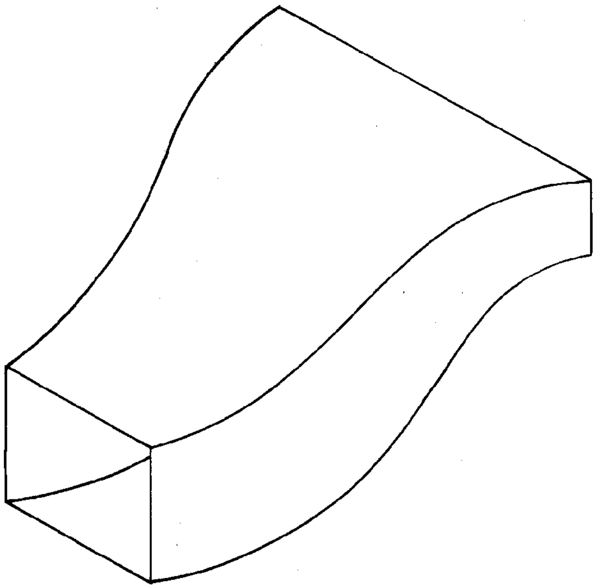


Figure 11-30. Transition jump.

(figs. 11-28 and 11-29). A jump may also be combined with a transition as shown in figures 11-30 and 11-31.

11-12. Takeoff Fittings

Connecting fittings between trunk ducts and branches are known as "takeoffs." Takeoff fittings may be streamlined with a round throat and a corresponding reduction in trunk size, as shown in figure 11-32, or they may be simply tapped on the side or top of the trunk, as shown in figures 11-33 and 11-34. To reduce friction at the takeoff, the velocity of the air in the branch ducts should be at least equal to that in the trunk. If tapped fittings are used, minimum takeoff resistance is obtained when the velocity in the branch duct is about 2½ times the velocity in the trunk. Patterns for these three fittings are shown in figures 11-35, 11-36 and 11-37. For minimum resistance in tapped takeoff fittings the dimensions given in the tables accompanying the drawings should be adhered to.

11-13. Fan Discharge Connections

As air velocities at the outlet of the scroll of a centrifugal fan are not uniform, being highest at the outer edge of the scroll, particular care must be taken to insure that turbulence is held to a minimum in fittings connected to a fan outlet. The effect of the relative positions of a fan and its outlet connection are shown in figure 11-38. Where room for the optimum discharge connection is not available, turning vanes should be installed.

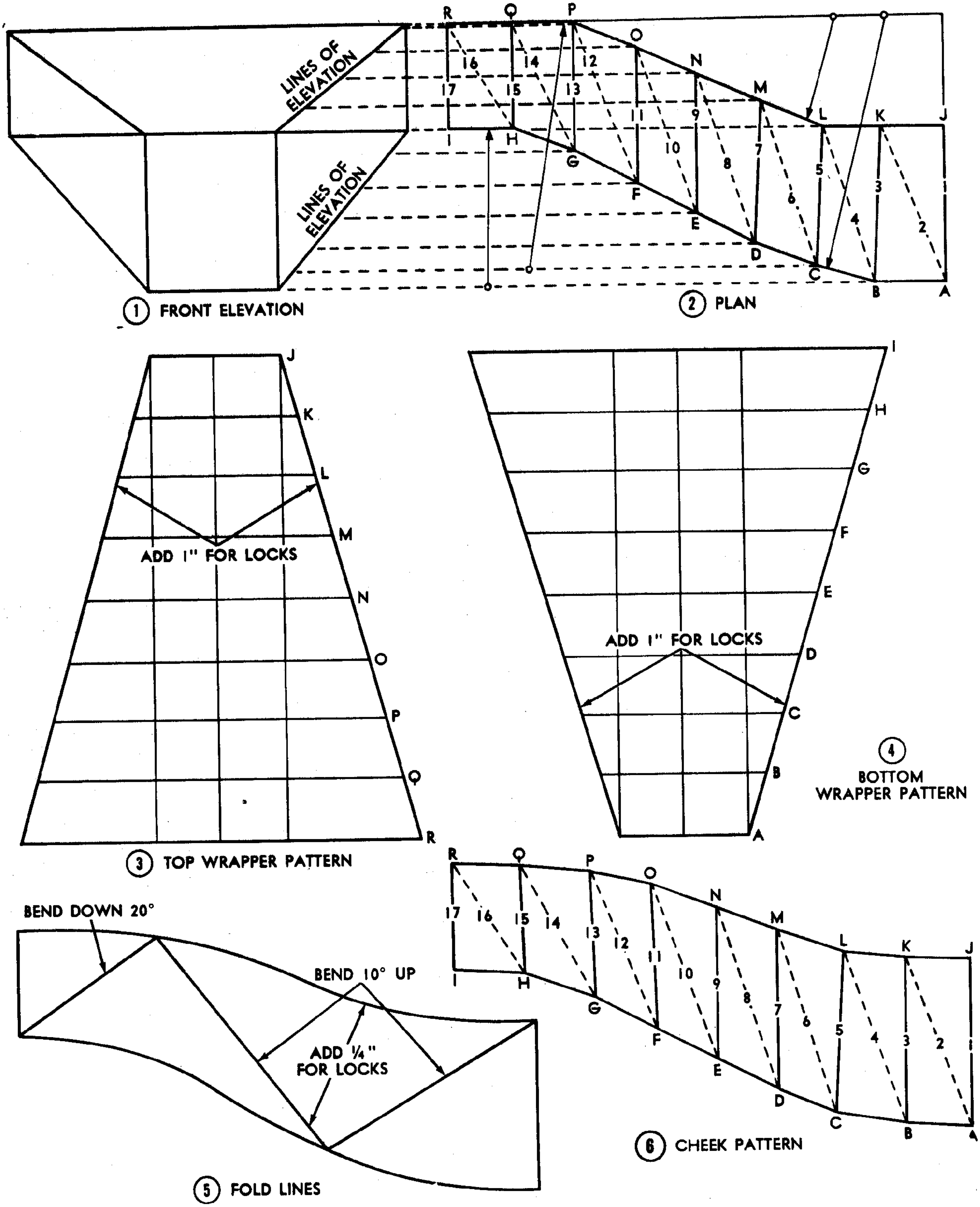


Figure 11-31. Pattern for transition jump.

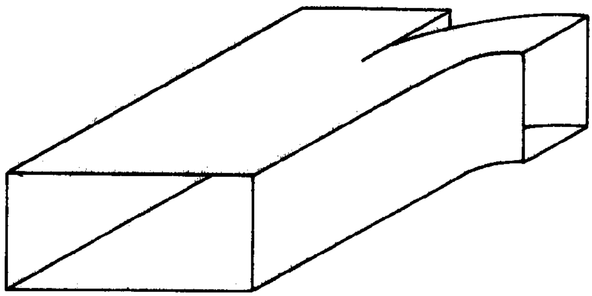
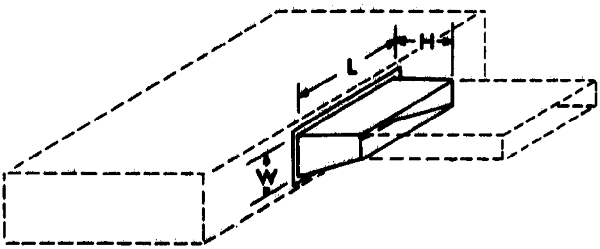
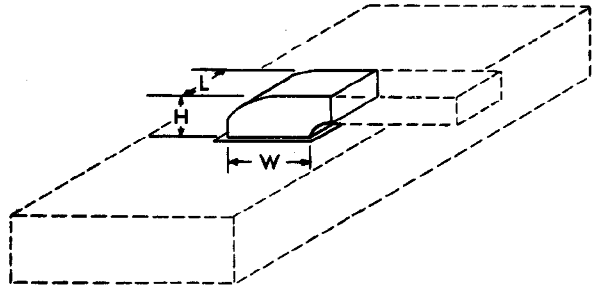


Figure 11-32. Round throat side takeoff.



BRANCH DUCT	SUGGESTED TAKE-OFF FITTING DIMENSIONS		
SIZE	L	W	H
10" x 3¼"	10"	7"	8"
12" x 3¼"	12"	7"	9"
14" x 3¼"	14"	7"	10"
14" x 5"	14"	10"	11"

Figure 11-33. Tapped side takeoff.



BRANCH DUCT	SUGGESTED TAKE-OFF FITTING DIMENSIONS		
SIZE	L	W	H
10" x 3¼"	10"	7"	8"
12" x 3¼"	12"	7"	9"
14" x 3¼"	14"	7"	10"
14" x 5"	14"	10"	11"

Figure 11-34. Top takeoff.

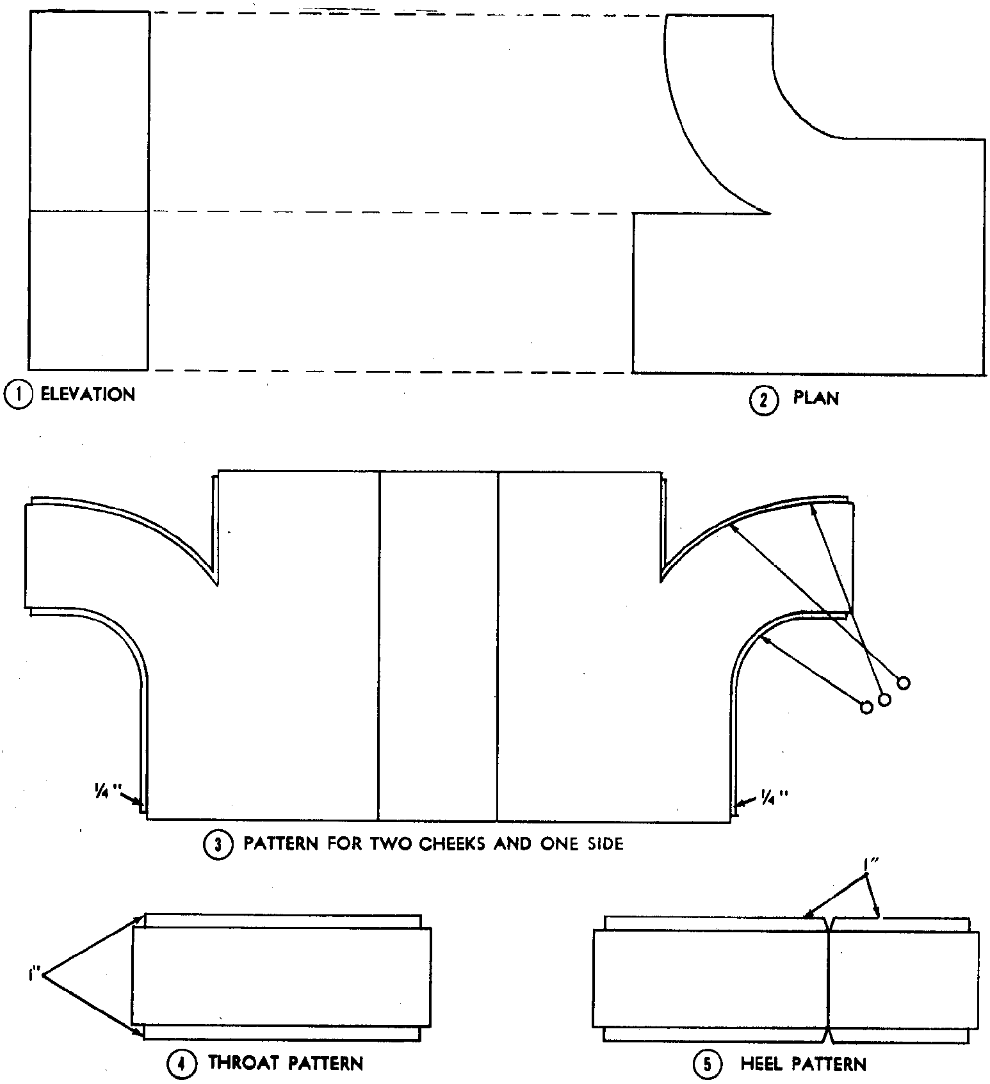


Figure 11-35. Pattern for round throat side takeoff.

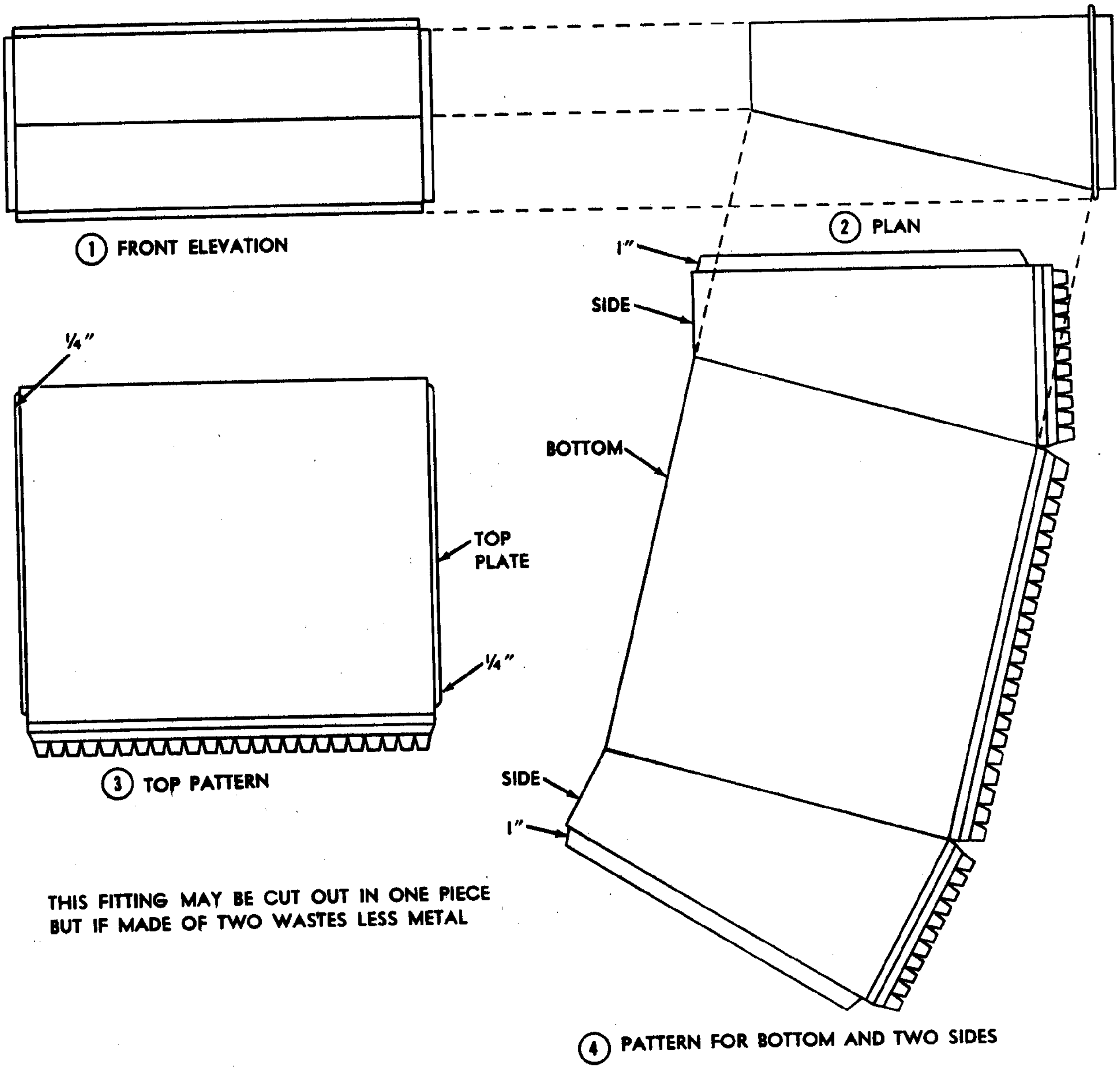


Figure 11-36. Pattern for tapped side takeoff.

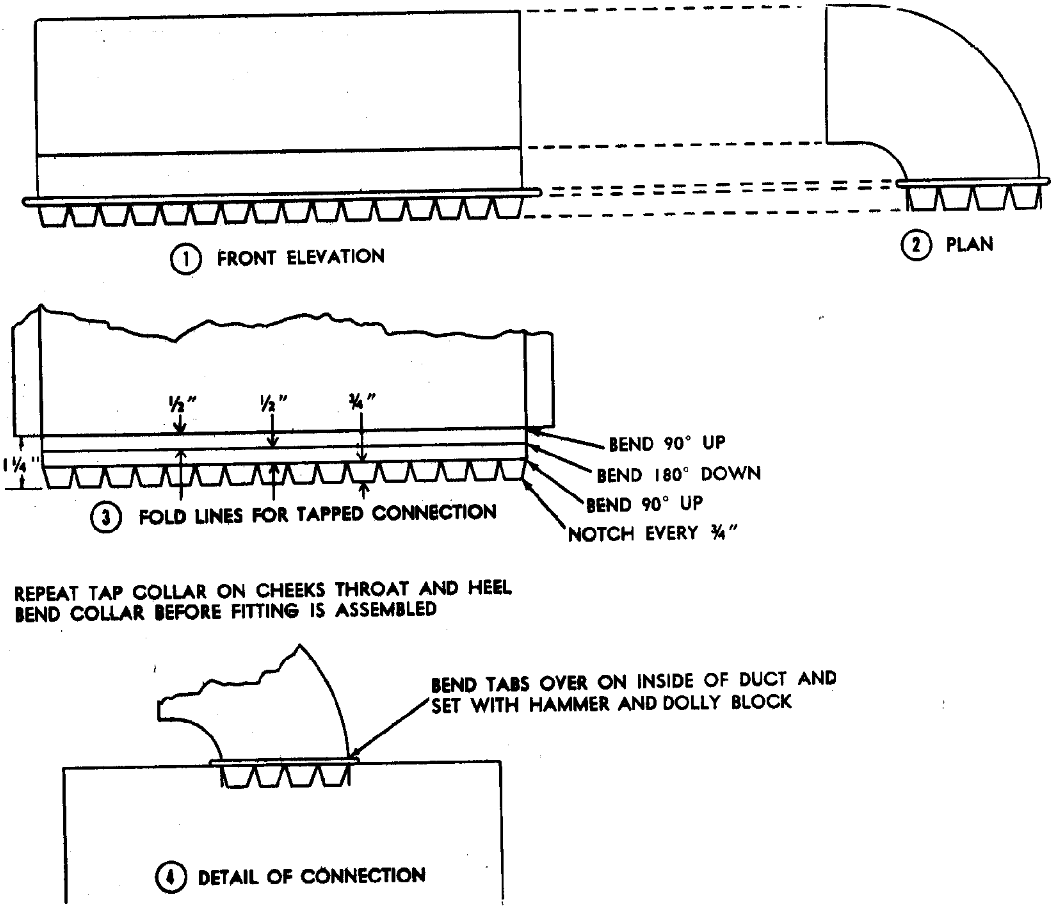


Figure 11–37. Pattern for top takeoff.

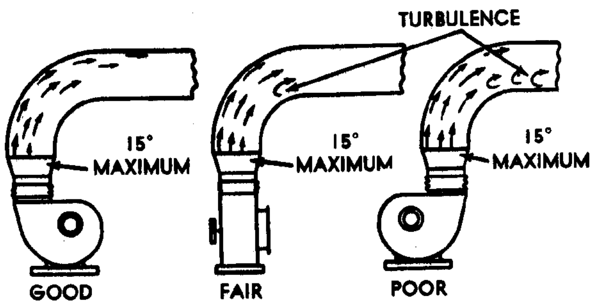


Figure 11–38. Fan discharge connections.

Section III. FIELD PRACTICE

11–14. Duct Construction

a. Material. Although air vents can be constucted of wood, composition board, masonry, or other materials used in building construction, this section is confined to the use of the most commonly used material, sheet metal. Galvanized iron and aluminim are the materials generally used although black iron may be used when work is of a temporary nature. The larger the ducts, the heavier the gage of metal required in order to provide proper strength and rigidity. A table of recommended sheet metal gages for construction of ducts of various widths is given in table 0-1.

b. Seams. Seams are used to join two metal edges in the construction of a length of duct or a duct fitting. Types of seams generally used are shown in figure 11-39. The grooved seam which is used for joining two sheets of metal in the same plane is made by forming a single fold along the edge of each sheet, hooking these folds together, and then laying the seam on a flat surface and hammering it down with a grooving tool which straddles the seam. Ducts and fittings are most frequently assembled by use of the Pittsburgh seam running along one edge of a rectangular duct and on all four edges of a fitting. This seam can be made in a brake but it has proven of such universal use that special forming machines are available. The method of assembling and locking a Pittsburgh seam is shown in figures 11-40 and 11-41.

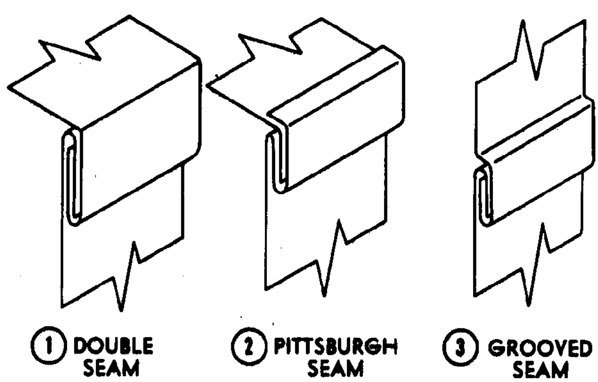


Figure 11-39. Sheet metal duct seams.

c. Joints. Methods of making connections between ducts and fittings are shown in figure 11-42. A connection combining two S slips and two drive slips, known as the "S-and-drive," is most frequently used. To assemble this connection, S slips are first placed on two opposite edges of one of the fittings to be joined. These S slips are usually applied to the long side of the duct (fig. 11-43). The second piece is then inserted in the slips and the two pieces are held together by inserting drive slips along the other two sides as shown in figure 11-44. After the drive slips are driven home they are locked in place by bending over the ends to close the corner and lock the drive slips in place (fig. 11-45), completing the joint shown in figure 11-46.

Figure 11-40. Assembly of Pittsburgh seam.

d. Reinforcement and Support. Ducts 24 inches or more in width require a reinforcement at the joint for strength. Types of reinforced seams used are shown in figure 11-47 and recommendations as to their use are given in table O-1. In addition, large flat surfaces should be cross-broken as shown in figure 11-48.

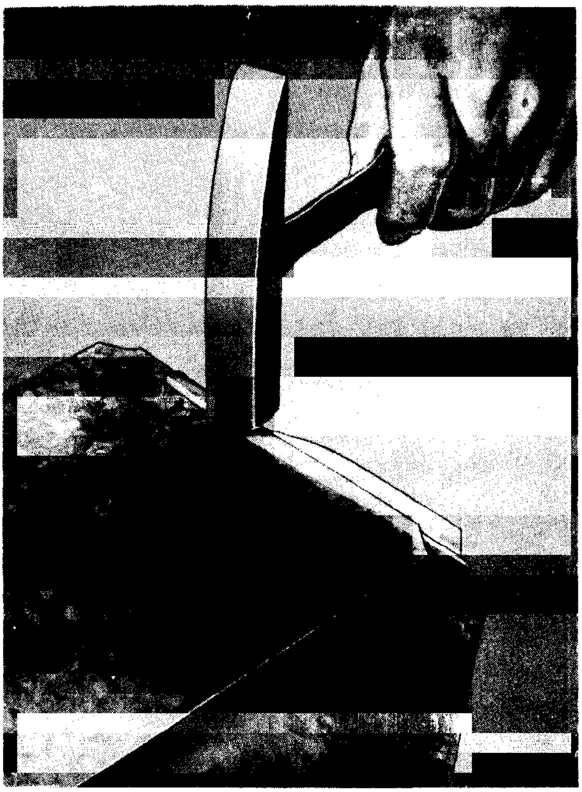


Figure 11-41. Closing a Pittsburgh seam.

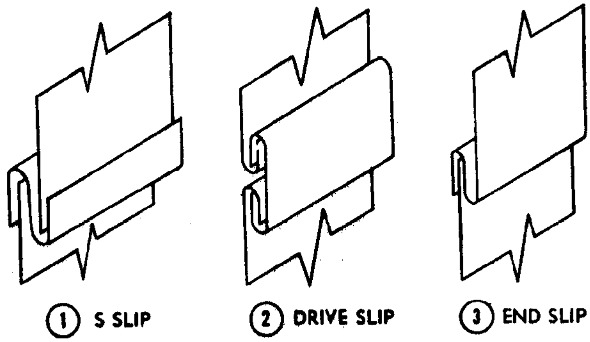


Figure 11-42. Methods of connecting ducts.

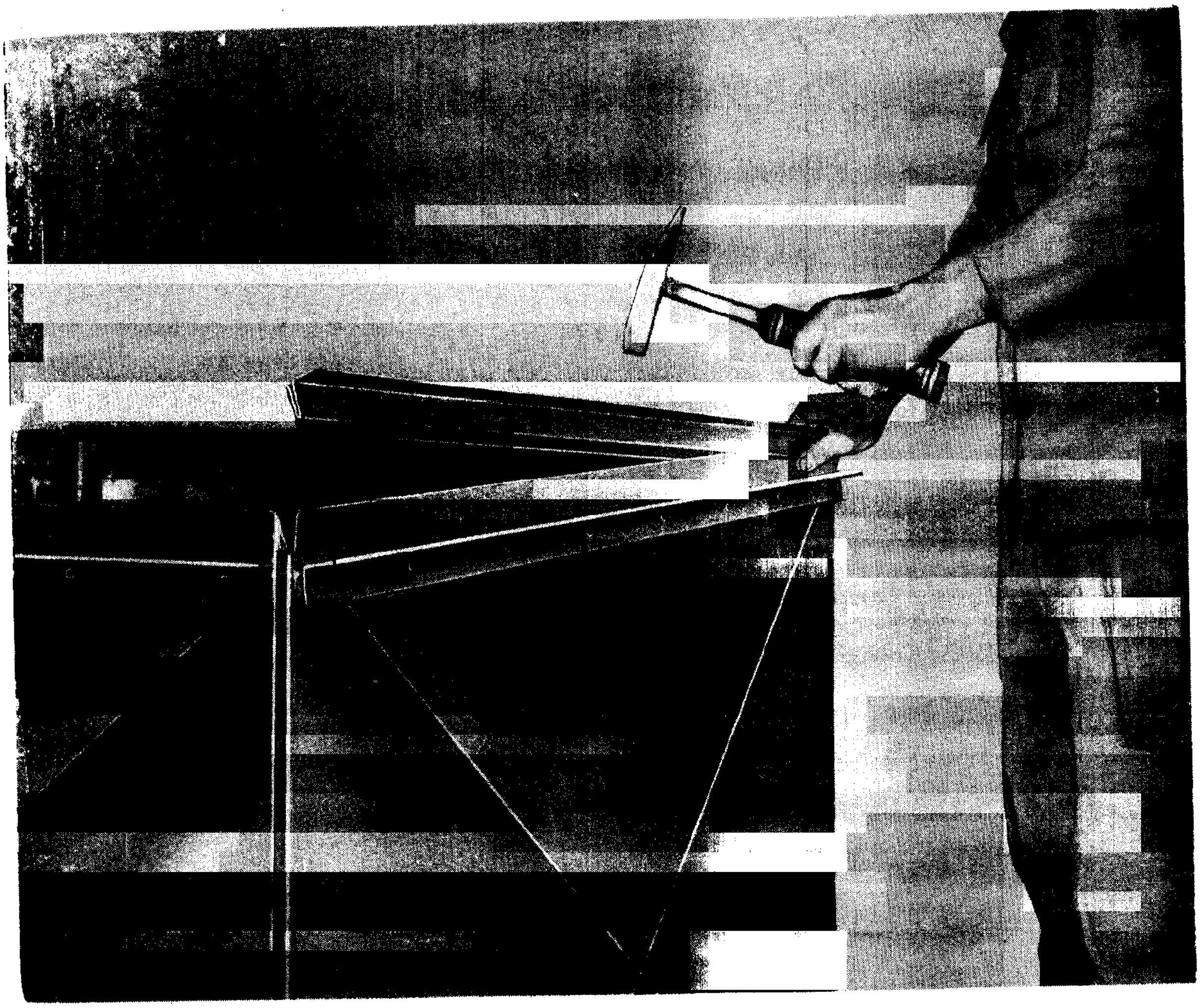


Figure 11-43. Placing S *slips for* "S-*and-drive*" *connection.*

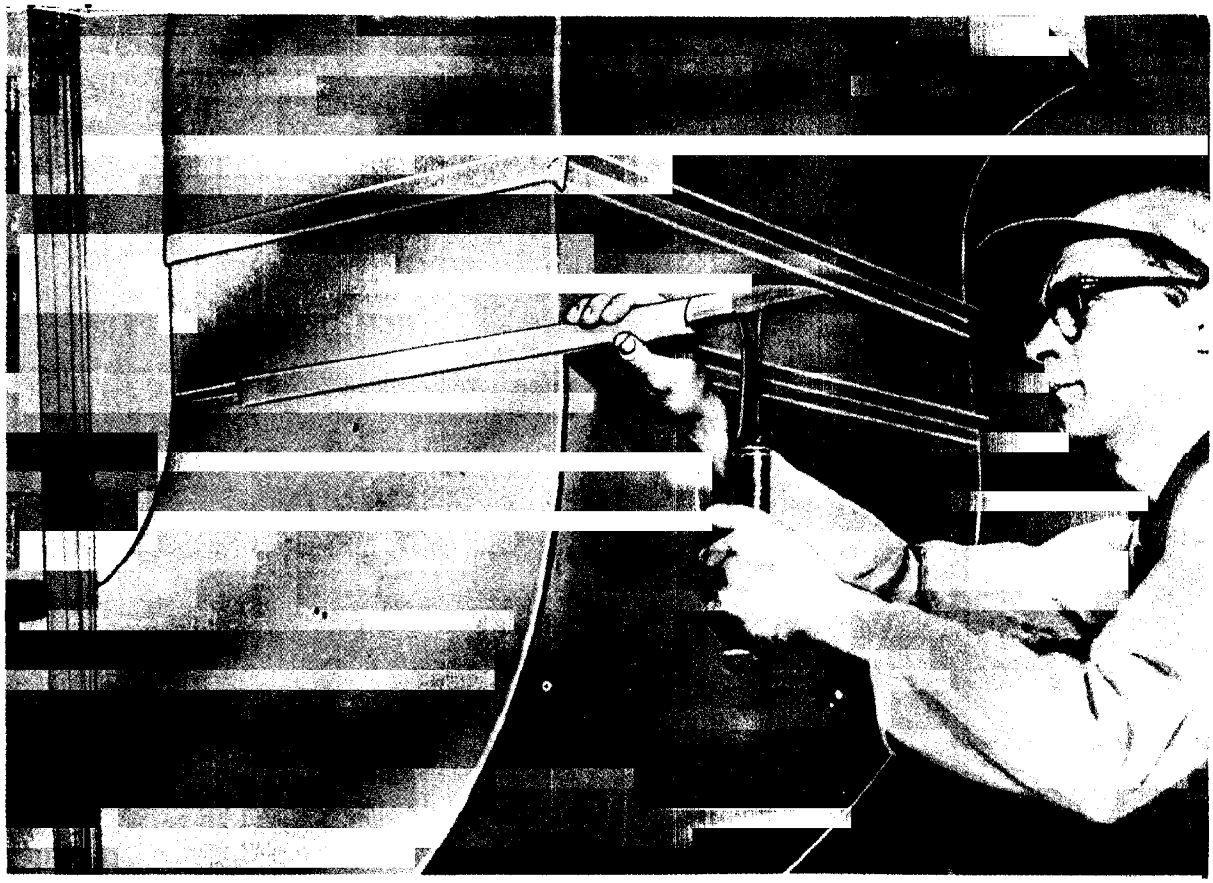


Figure 11-44. Inserting drive slips

Figure 11-45. Bending drive slips to complete joint.

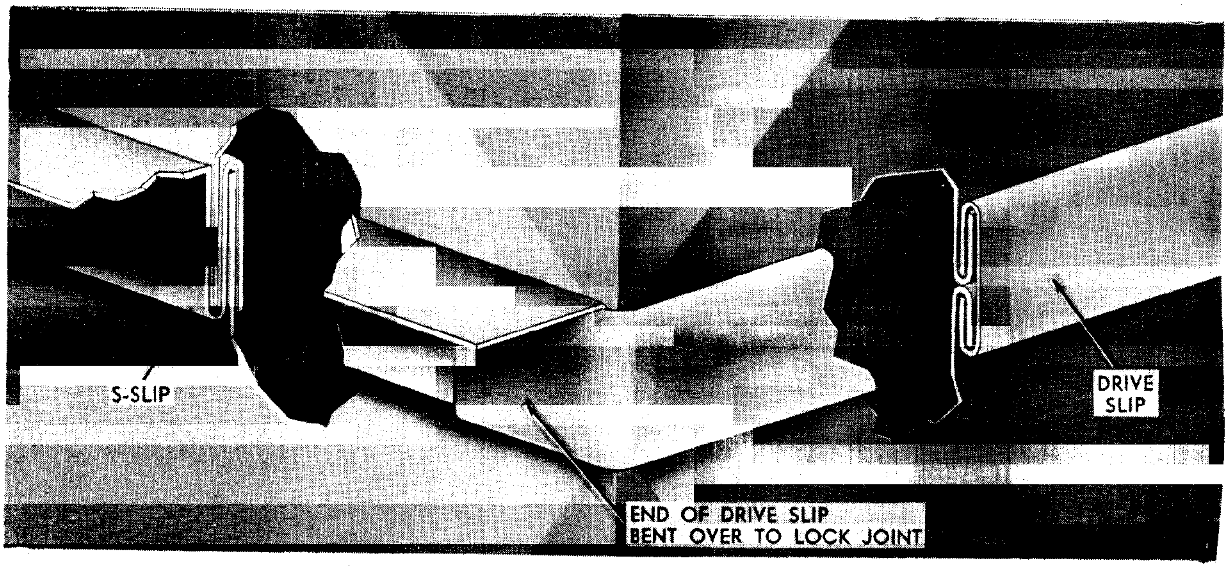


Figure 11-46. Completed "S-and-drive" connection.

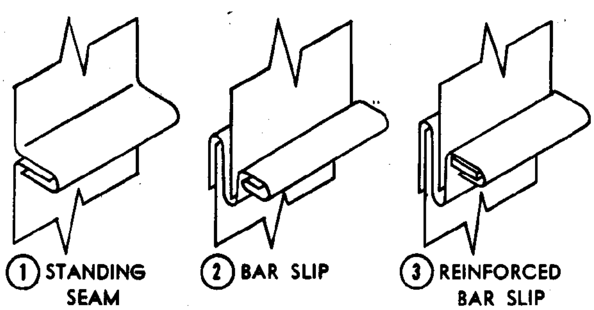


Figure 11-47. Standing and reinforced seams.

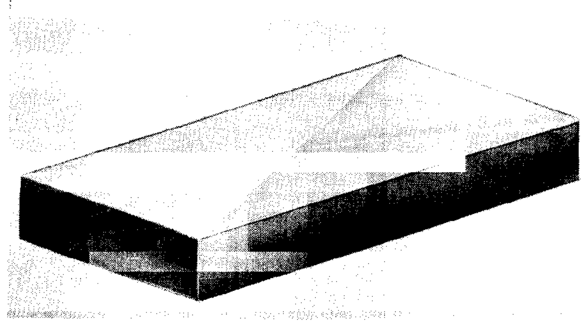


Figure 11-48. Cross-broken flat surfaces.

11-15. Flexible Connections

Inlet and outlet duct connections to all fans or other equipment which may create vibration should be made with a heavy canvas (fig. 11-49). If there is any danger of fire, either within or without the ducts, make the connector of asbestos cloth.

11-16. Obstruction in Ducts

Do not run pipes, wire, or structural members through ducts if it is at all possible to avoid it. If such obstructions cannot be avoided, turbulence should be reduced by enclosing the obstruction in a streamlined collar, as shown in figure 11-50. If necessary, increase the size of the ducts to keep at leat 90 percent of the duct area unobstructed.

11-17. Dampers

Equip all air duct systems which serve more than one outlet with dampers to permit adjustment of air flow. Install a damper in each branch duct, and where accessible locations can be found use the type shown in figure

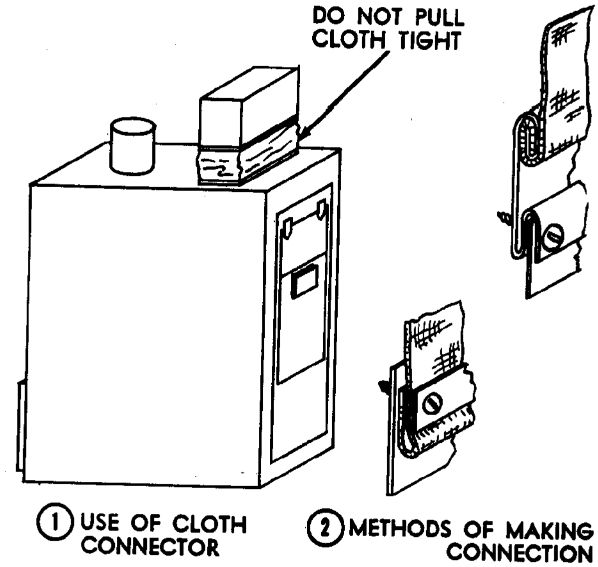


Figure 11-49. Flexible duct connection.

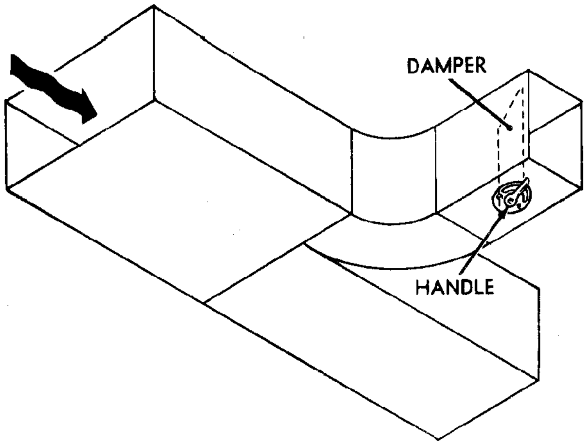


Figure 11-51. Volume damper.

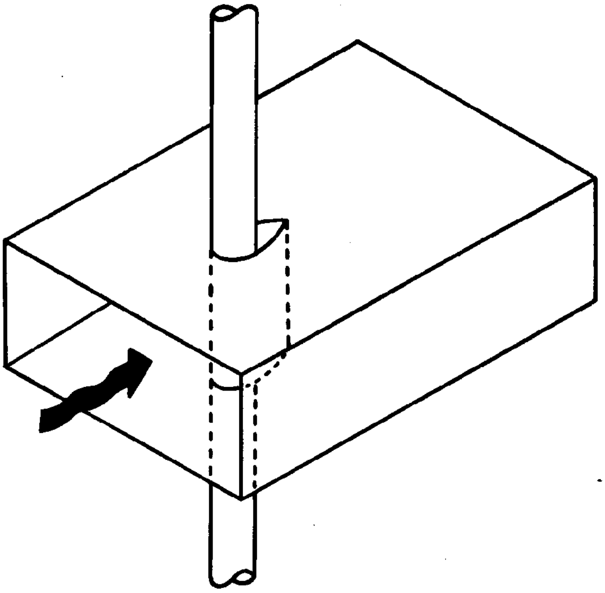


Figure 11-50. Easement around obstruction in ducts.

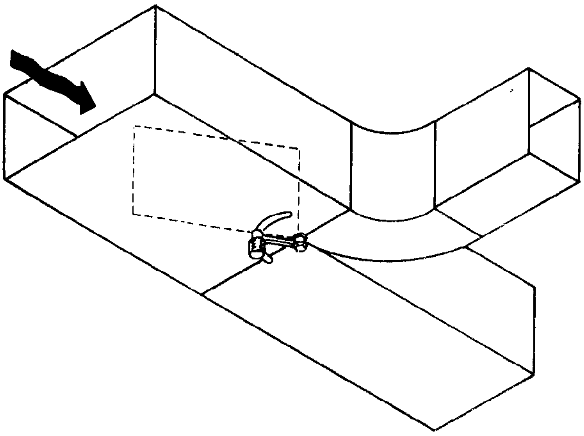


Figure 11-52. Splitter damper.

11-51. Also equip the dampers with a locking device and some means of indicating their position. Where there is sufficient room to make the length of the damper at least twice the width of the smaller of the two openings it serves, use the splitter type shown in figure 11-52 where practicable to reduce turbulence losses. Use the stack head type damper shown in figure 11-53 when it will not be necessary to change the damper position after the initial adjustment or when it is impossible to find accessible locations elsewhere in the duct system. When air adjustment is made with the assistance of air velocity measuring devices, these dampers have the added advantage of allowing one man to measure and adjust air flow simultaneously.

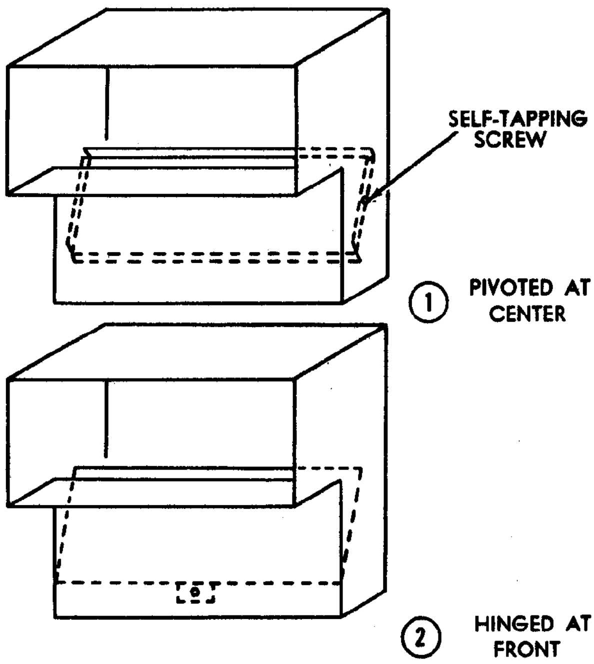


Figure 11-53. Stack head dampers.